WEINSHANK

The Hot Blast System of Heating and Ventilating

Mechanical Engineering

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THE HOT BLAST SYSTEM OF HEATING AND VENTILATING

BY

THEODORE WEINSHANK

B. S. University of Illinois, 1896

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

THEODORE WEINSHANK, B.S., 1896

ENTITLED THE HOT BLAST SYSTEM OF HEATING AND VENTILATING

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF MECHANICAL ENGINEER

In Charge of Major Work

L. P. Breckenridge

Head of Department

Recommendation concurred in:

James M White

A. P. Carman

Committee on Final Examination

HOT BLAST HEATING & VENTILATION.

Introduction.

Air, being the prime supporter of life, health is dependent on the composition of the atmosphere. Although a simple mechanical mixture, yet certain gases of which it is composed, exist in almost unalterable proportion in a normal atmosphere. Oxygen and nitrogen, the principal constituents, are present in very nearly the proportion of 1 part of oxygen to 4 parts of nitrogen. Carbonic acid gas, the result of all perfect combustion, either slow or rapid, exists in the very small proportion of 3 to 4 parts in 10000 of pure air.

The following table gives the composition of pure air and of respired air:

	Pure Air.	Respired Air.
Oxygen	20.35	16.2
Nitrogen	78.10	75.4
Carbon Dioxide	0.03 to 0.04	3.4
Water Vapor	1.5 (variable)	5.

Carbonic acid gas, unless present in very large quantities, is not in itself either harmful or disagreeable, but the amount present, if due to respiration, is a trustworthy indication of the state of purity of the air because the poisonous effect of

respired air is believed to be due to organic matter, which is exhaled from the lungs in direct proportion to the amount of carbon dioxide exhaled.

When carbonic acid is present in excess of 10 parts in 10000 parts of air, a feeling of weariness and stuffiness, accompanied by a headache, is usually experienced; while even with 8 parts in 10000 parts, a room is considered close. For adequate ventilation the limit is usually placed at 6 to 7 parts in 10000, thus allowing an increase of 2 to 3 parts per 10000 over that present in outdoor air, which may be considered to contain 4 parts in 10000 under ordinary conditions of a populous district.

Under the general conditions of outdoor air an average adult man, when sitting at rest as in an audience, makes sixteen respirations per minute of 30 cubic inches each, or 480 cubic inches per minute. The air thus inhaled will consist of about 1/5 oxygen and 4/5 nitrogen, together with about 1.5 per cent vapor and .04 per cent carbonic acid. The exhaled air will have been warmed from 70 degrees to 90 degrees and notwithstanding the increased proportion of carbonic acid, which is heavier than air, will, owing to the increase of temperature, be about 3 per cent lighter than when inhaled. It will also be found to have lost about 1/5 of its oxygen by the formation of carbonic acid, which will have increased about one hundred fold, thus forming about 4 per cent, while the vapor will form about 5 per cent of the volume. Add to this the small amount given

off from the surface of the skin, and it will be found that at least 4 cubic feet of air per minute will be required to carry away the vapor. As it is impossible to immediately remove the spent air from the lungs, which contains about 400 parts of carbonic acid gas in 10000, without its being diffused in the atmosphere, it is necessary to dilute it to such a degree that the standard of 6 or 7 parts in 10000 will be maintained. Ventilation therefore is in effect but a process of dilution and when the condition of the air discharged from the lungs is known, and the allowable degree of vitiation to be maintained in the apartments is decided, the necessary constant supply of fresh air to maintain any given standard may be very easily decided.

So far the contamination of the air has been ascribed to respiration, but where smoke, dust, noxious gases, or germs are produced, and above all when the illumination is furnished by candles, lamps, or gas, an additional air supply must be provided.

The usual specification for air supply per person is as follows:

	Cubic Feet per min.
Hospitals (ordinary)	35 to 40
Hospitals (epidemic)	80
Workshops	25
Prisons	30
Theaters	20 to 30
Meeting halls	20
Schools (per child)	30
Schools (per adult)	40

I have found in practice that these volumes almost invariably require at least 6 changes of air per hour, which is a satisfactory amount of air from the heating standpoint as well.

There are two systems of ventilation, namely the Plenum and the Exhaust. In the first, the air is PUT where it is wanted. In the second, which by the way is being discarded as a failure, the air is exhausted from the building, thus forming a partial vacuum within the apartment so that all currents and leaks are inward. Nothing governs definitely the quantity or place of introduction of the air, and though heaters are placed at openings, through which fresh air is supposed to be drawn, a considerable quantity of air, following a path of less resistance, enters the building from undesirable sources and tends to contaminate the air instead of purifying it.

On the other hand, when the air is forced in , with the volume, temperature, and point of admission completely under

control, all spaces are filled with air under a slight pressure and the leakage is outward.

Buildings in which hot blast heating is being used can be classified in seven groups:

A - School Houses
B - Churches
C - Theaters and Assembly Rooms
D - Hospitals
E - Factories
F - Dry Rooms
G - Railroad Round Houses.

SCHOOL HOUSES:

There are six different methods of heating school houses:

1 - Single duct systemm automatically regulated
2 - Single duct hot air only
3 - Double duct, automatically regulated
4 - Double duct, hand regulated
5 - Reinforced by indirect radiation at bottom of flue
6 - Plenum and exhaust system combined.

For the first method the dimensions of the fan, coils, air ducts, air flues and supply and vent registers are determined as follows:

An average school house will require a fan run at 1/2 ounce pressure, which will give a discharge velocity of 1800 feet per minute, and an average condensation of about 750 B. T. U. per hour, per square foot of pipe in the heaters.

Plate 14091 is the result of a three years' series of tests, covering about 200 experiments. Primarily I endeavored to determine the amount of steam condensed per square foot per

hour under different conditions. This also enabled me to obtain results showing the temperature rise, the B.T.U's transmitted to the air, etc. The velocities given on line 11 are in the duct leading to the coils and are about half that through the coils. This table has been checked by a number of authorities and by different manufacturers. I am glad to say that my results have been duplicated a number of times, but up to the present, have not been improved upon.

The American Radiator Company recently employed Professor Kinealey to conduct a series of tests on their newly designed hot blast cast iron section. These results were published in trade papers and again confirmed the figures I have obtained, namely, that 750 B.T.U. per square foot per hour, is a safe basis to figure on the number of square feet of radiation required for a certain amount of air.

It is desirable to keep the duct velocity down to 800 or 1000 feet and the flue velocity to 600 or 800 feet, depending upon the size. The velocity should always decrease as the volume of air decreases, and the actual sizes are usually based upon the designer's judgment rather than upon theoretical considerations. Register velocities are usually 300 feet per minute.

The floor space of each school room is divided by 15, to determine the number of pupils, and on the basis of 30 cubic feet per minute per pupil, we find the required amount of air for each school room. For assembly rooms, hallways, offices

and recitation rooms, where the pupils come and go, an air change every ten minutes, or six times per hour, is allowed. This data should be scheduled as shown in Table # 1.

Where rooms are used for class rooms, the cubic contents should not be taken as the basis for determining the amount of air required. For example, room # 101, having a cubic contents of 10104, calls for an air delivery of 1500 cubic feet per minute, which would be less than a change of every eight minutes. The floor space in room # 101 being 78 square feet, the number of pupils will be about 50. 50 X 30, or 1500, will be the required amount of air.

Dividing 1500 by 600, which is the velocity of the air through the flue, we obtain 2 1/2 square feet as the area; or which is equivalent to 16" X 22". The vent flue is figured same as the supply flue, namely, 16" X 22".

To determine the area of the register, we multiply the area of the flue by 2, and this will give the face area of the register. Referring again to room # 101; the area of the flue is 16" X 22", or about 350 square inches; multiplied by 2, we have the face of the register 700 square inches. The register nearest this area is a 24" X 30".

The area of the duct is figured by dividing the amount of air to be delivered by 800. Again referring to room # 101, where the amount of air is 1500 cubic feet, the area of the duct is 1500 divided by 800, or an area equal to 13" X 18".

Adding up the air required for all the rooms, we have a total of 38,300 cubic feet of air.

To determine size of fan, divide the total amount of air required for the entire building by 1800, or the velocity of the air through the outlet; the quotient, or the result will be the area of the outlet of the fan required in square feet.

Referring to any standard catalog of blower manufacturers, the size of the fan will be obtained. In the case referred to in Table # 1, 38,300 cubic feet of air divided by 1800 will be about 21 square feet. Referring to a blower catalog, we find that a blower having the nearest to 21 square feet, is one having an outlet of 4 1/2 X 5, or 22 1/2 square feet. The fan corresponding to such an outlet, is one having a 9 foot wheel.

If a double discharge fan is used, then the amount of air required at each end of the outlets is to be divided by 1800, or the velocity of the air, in which case the area of each outlet will be given.

The capacity of the heater, or the number of 1" pipe for the fan, is determined in the same manner as ordinary heating surface is determined for indirect heating, viz:

$$R = \frac{L}{750}$$

Where L = B.T.U. losses

750 = B.T.U. from each square foot of 1" pipe.

I find from practice that the free area of the heater, or the total space between the pipes, must be such, that the velocity of the air through the heater will not be greater than 1000 feet per minute. The result so obtained will invariably

correspond to the area of inlet of the selected fan, increased by 25 per cent, and is nearly equal to the theoretically calculated surface.

Referring to Table # 1, from which we found that a 9 foot fan is required delivering about 40,000 cubic feet of air per minute at 1/2 ounce pressure, we can readily determine the free area of the heater. Dividing 40,000 by 1000, gives a free area equal to 40 square feet.

The construction of standard blast sections is such that the total face of the heater is twice as large as the free area, or in other words, the free area through a standard heater is about 50 per cent of the face area of the heater. On this basis we find that the heater required for the 9 foot fan would have to have a face area of 80 square feet.

The nearest standard size coil is 6 feet wide and 7 feet high, and a double group of same would be 84 square feet face area.

The following sizes of heaters are standard and used by all manufacturers as stock sizes:

3' x 3'	having about	600	sq.in.	free	area	between	pipes.
3' x 4'	" "	700	"	"	"	"	"
4' x 5'	" "	1100	"	"	"	"	"
5' x 6'	" "	1750	"	"	"	"	"
6' x 7'	" "	2500	"	"	"	"	"

7' x 8', or 2-row sections having a free area of about 3300 sq.in., usually made of 1 1/4" pipe.

Having the above data, the designer can use either single group, double group, or possibly triple group, so as to obtain the free area required.

The coils in connection with the fan are usually divided as follows: A number of coils are placed at the inlet of the fan, so calculated that the air at 10 below zero (which is the basis of calculation), after passing through the heater, will be raised to 60 degrees above. The coils at the discharge of the fan are usually so arranged, that the latter air, namely, at 60 degrees, will be reheated to a maximum temperature of 140 degrees.

In the middle states the tempering coil is designed from 6 to 8 rows. In the northern states the tempering coils are designed from 8 to 10 rows. South of the Ohio River the tempering coils are built of 4 rows. The reheating coils are designed for from 12 to 16 rows.

For the heating coils I find that 12 rows is the least that it is advisable to use in any hot blast work, especially so where low pressure is used.

In the hot blast system of heating, where automatic regulation is used, the fan is hardly ever connected direct to the ducts. A hot air or blast chamber is so constructed that temperature regulation can be provided for all rooms. The construction of this chamber is shown on plate #14045 and #14046.

On these plates great care has been taken in designing the ducts to avoid sharp bends and to have all of the same depth, so as to cheapen construction as well as make them uniform. Where ducts enter flues, a deflector is placed at the outlet to avoid eddy currents at the discharge.

The registers for the discharge are usually placed not less than 8 feet from the floor and the vent registers must be as close to the floor as possible, so as to remove the coldest air which is at the floor.

The vent flues terminate in the attic and the entire attic is made air tight, and one ventilator placed on the roof, so that the foul air will be forced into the attic, and thence through a ventilator to the atmosphere. The ventilator is of such construction that it will prevent down drafts while the fan is not in operation and it has a hand regulated damper, to be regulated from the basement so it can be easily closed when the fan is not running.

Each of the ducts leading from the plenum chamber or the blast chamber, is provided with a damper, automatically controlled by a thermostat in each room. The duty of this automatic damper is to shut off the hot air and open the cold air damper, when the temperature in the room rises above a certain degree. By this arrangement there is a constant supply of air being forced into the school room, whether hot or tempered, thus retaining the constant supply of air for which it has been designed. Plate #14045 illustrates a double discharge fan, and plate #14046 a single discharge fan.

<u>Single Duct, Hot Air Only</u> - See plate #14049.

Under this system the fan and the coils are designed as in case #1, viz: as per table #2, but the hot air from the fan is distributed through one single pipe making a connection at the bottom of each flue. This system, while still used in

isolated cases, is undesirable for school houses, as there is only one temperature of air being delivered, and when the room becomes overheated, the register is necessarily shut off and thus the heat as well as the ventilation is discontinued. The air then becomes foul and remains so until the temperature of the room, or rooms, becomes so cold that the occupants are compelled to open the registers.

The velocity of the air in the main duct, or the main branch, is figured at about 1500 feet per minute, the branches from the main duct to the bottom of the flue at about 1000 feet per minute, and the velocity through the flue at 600 feet per minute, and through the register at 350 feet per minute.

This system is not used extensively with the exception of the rural districts, where the heating question only is considered.

Double Duct Automatically Regulated - Plate #14048.

Under this system the fans and coils are designed the same as in case #1, and the heater which is usually placed in front of the outlet of the fan, is set up on piers with a by-pass underneath, and the air is made to clow through the heater and under same. At the other side of the heater, two ducts are provided, the one to receive the hot air being placed near the ceiling, with a parallel pipe directly underneath to carry the cold, or tempered air.

From the main trunks branches run to each stack or flue, and a mixing damper is placed at the bottom of each flue, which is controlled by a thermostatic regulator placed inside of the

room to which this particular stack leads. By this arrangement a constant supply of air is furnished to each room, but the cost of such installation is greater than a single pipe, and the operation of the automatic damper is often a source of considerable trouble as the damper is placed in a position not easily accessible for adjustment.

Plate #14048 is a typical design for a double pipe system. I have illustrated on the left hand of the drawing a possible design which is often used where the building is symmetrical and has a long hallway like in a hospital or hotel. The section through apparatus B shows a two-pipe system at the ceiling of the basement as described. Section through apparatus A shows a case where the ceiling in the entire hallway has been furred and the entire space made into an air duct, placing a partition between the hot and cold air. By such an arrangement it is possible to place the automatic regulating dampers at the base of each flue and the apparatus operating the dampers is placed in the hallway against the wall. Such construction as illustrated with apparatus A is very desirable if the construction of the building permits it.

The tempering coils placed at the inlet of each of the fans, are placed on piers and the by-pass underneath is so arranged, that it can be controlled automatically so as to maintain a temperature of 60 degrees for the tempered air supply.

<u>Double Pipe Hand Regulated</u>:

Under this system the two pipes mentioned before are run parallel, but the mixing damper is not controlled automatically.

It is controlled with a chain from the room to which same leads. This system was the original hot blast work installed, but is being changed to automatic wherever possible. There are very few new systems being installed today having such an arrangement.

Reinforced With Direct Radiation at Stacks or in Rooms.

Under this system the fan is supplied with sufficient coils, either "draw through", or "blow through", to temper the air, or enough to raise the temperature from 10 below to 70 above. Only one duct leads from the blower,and branches run to the bottom of each stack or flue, where an indirect radiator is placed, of such size as to reheat the air from 70 to 120. This air at a temperature of 120 is forced into the rooms and discharged in the usual way about 8 feet above the floor. There is no regulation of temperature in connection with this system with the exception of a few attempts made to put in an automatic regulator in the steam supply to the indirect reheaters. This, however, has proven to be unsatisfactory, and is used only in very exceptional cases.

Another method of reinforced hot blast heating, often used in states where the temperature falls below zero for a considerable length of time, is to place direct radiation in the rooms and reinforce same with hot blast for ventilation. The method of calculating is as follows:

I figure on the fan and coils as though the entire building was to be heated with the hot blast system. Then I figure the direct radiation as though the building was to be heated

by direct radiation. Then I combine the two systems in the following manner: I use 75 per cent of the blast apparatus so designed, and 50 per cent of the direct radiation as designed. The coils are designed to raise the temperature of the air to 90 degrees, which usually requires 14 rows deep. This latter method has proven very satisfactory through the states of Minnesota, Wisconsin, Iowa, Illinois and Michigan.

Plenum and Exhaust:

The single duct automatic regulating system is also used in connection with a so-called exhaust system. The school rooms, hallways, assembly rooms and offices are heated with the hot blast system, having automatic regulation, but no air is supplied to the toilet rooms, wash rooms or swimming pools - the latter being heated with direct radiation.

The air from these latter rooms is exhausted with a fan centrally located and so arranged that the entire air from the building is flowing towards these latter rooms, and from them through the vent flues to the exhaust fan. By this means, the impure air from the building flows toward the toilet rooms, and thence to the exhaust fan instead of the foul air in the toilet rooms finding its way into the hallways, when the doors are open. This latter system is being largely used today, and the number of tests conducted by me have proven that the change of air through the building, as well as through the hallways, etc., has been very satisfactory.

From tests conducted, and also after a thorough investigation of the statistics obtained by officials of public institu-

tions, I have found that the rate of attendance in school rooms has increased, and the rate of sickness has largely decreased during the last eight or ten years since the heating and ventilation of schools has been given the proper consideration.

CHURCHES, THEATERS and ASSEMBLY ROOMS - Plates 14044 and 14054

The churches and theaters that have no occupied basements are today exclusively heated by the hot blast system in the following manner:

After determining the number of occupants of the building, namely, about 7 square feet of floor space per person, the amount of air, fan, coils, etc., is easily determined, as explained before under the heading of "School Houses", namely, on the basis of 30 cubic feet per person per minute.

The distribution of air in all modern theaters and churches is obtained by forming a plenum chamber under the entire lower floor. The fan and coils are placed somewhere outside of this plenum chamber, usually at the lowest portion of the floor level, and the entire amount of air required is forced into this chamber. Under each seat on the lower floor, an opening is provided usually 5, or not more than 6 inches in diameter, with a small cap over the outlet. The air from the blast chamber finds its way through these openings into the main hall.

The velocity through these openings is usually figured about 200 feet per minute. In cases where a register face is placed on the side of the seat or chair, and the legs of the

chair forming a duct which is connected with the blast chamber, the velocity through that register should be not greater than 100 to 150 feet per minute. This latter fact the writer found after making a number of experiments at the Pabst Theater in Milwaukee, where such an arrangement is made. I found that an increase of velocity through the registers, caused annoyance to the person sitting near same.

At the rear end of the theater or assembly room, large ducts are built with openings provided at each gallery level, and an exhaust fan is placed in the attic, or basement, to draw the air out through them. This exhaust fan not only increases the circulation of the air entering from and at the floor level, but also improves the acoustics of the halls.

A sufficient amount of direct radiation is usually placed in the lobbies and at the entrance so as to prevent any cold drafts when the doors are open, and to assist in heating the air quickly before the beginning of a performance.

In some individual cases attempts have been made to place the fan in the basement, from which ducts are run under the main floor discharging the air into flues, which terminate in a number of registers opening around the outside wall, about 8 feet above the floor. This has proven unsatisfactory because the draft is very uncomfortable for those near the openings.

Plates #14044 and #14054 illustrate a design for a small theater. The design is such that the entire air travels to the rear of the building, then downward through flues into a main duct, and then to an exhaust fan placed in one corner of

the building.

HOSPITALS:

Modern hospitals are heated by the following methods:

Automatic regulating system, same as school houses.
Hot blast with reinforced indirect at the bottom of each flue.
Hot air only.
Combination system.

The first system is designed similar to the system for school houses. The basis of calculation for fan and coils is on 6 changes of air per hour. As in designing a hospital, the architects usually provide from 100 to 150 square feet per bed, the amount of air so furnished is not only sufficient for heating, but ample for thorough ventilation of wards, or private rooms. The rooms in hospitals, as a rule, are narrow and long, and special care must be taken to prevent drafts and to secure equal distribution of air throughout the room. To accomplish this the air should be discharged toward the windows and the vents be placed alongside the discharge flues. Thus the air leaving the hot air register does not fall toward the floor until it reaches the opposite side or the windows, and after cooling, will drop toward the floor and flow toward the vent flue without causing drafts.

Under the second system the fan and coils are designed for ventilation only and sufficient coils used to raise the air from 10 below to 70 above; and the ducts designed as stated before, having a velocity of about 1500 feet, the air being reheated at the bottom of each flue with enough radiation to

raise the temperature to 120 degrees. This latter system is mostly used in Insane Asylums and Epileptic Wards, where there is danger of the patients coming in contact with hot radiators. The amount of air so supplied is figured on a basis of from four to six changes of air per hour.

The automatic regulating system is very seldom used in hospitals because of the expense.

FACTORIES:

Factories as a rule are heated by "hot air only", as the question of ventilation is solved indirectly by heating with hot blast, unless the air is used over and over again. There are two ways extensively used for heating factories:

1st. When the system is designed at the same time the factory is planned, and when the building is narrow and long. Flues are provided in the side walls, with outlets 8 feet high, and a fan is placed either in the middle of the plant, or at one end. The duct from the fan to the vertical flues is usually of masonry and run under the floor. See plate #14047 and #14050.

The fan and coils are estimated on a basis of a change of air three times per hour, thus providing a temperature of 60 degrees at 10 below zero outside. The coils are designed for either high pressure live steam, or low pressure, or exhaust steam. When high pressure is being used, the coils are usually designed 16 or 18 rows. If low pressure is used, the coils are designed 20 or 22 rows. The relative size of fans

and coils is figured so that the air will be discharged with a pressure of 1 ounce per square inch, which is about equivalent to a velocity of 2400 feet per minute at the outlet. The velocity through the ducts is figured on a basis of 2000 feet per minute, and in the flues at a velocity of 800 feet to 1000 feet per minute.

2nd. In modern factories, such as those of steel construction with a crane through the center, with wings at each side, the fans are placed either in the middle or at each end of the building, and a row of galvanized piping run at each side of the middle span and the air discharged through openings provided at each side at regular intervals.

The velocity through the main duct near the fan is figured at the same velocity as the air leaving the fan, viz: 2400 feet per minute. After deciding on the number of outlets to be taken out of the main trunk, and dividing the amount of air to be discharged from each opening by 1000 (which is the velocity at the outlet), the size of the outlets is so determined. After one or two outlets are taken out from the main duct, the area to be deducted from the main pipe should be 15 per cent less than the proportional reduction in volume. Continuingin this manner to the end of the supply pipe, an equal distribution of air will be maintained through the entire factory.

I had an opportunity to check up the equalization table, readily obtained in almost any catalog, and found same to be very accurate for use in connection with factory work, where the outlets are all of the same size.

ROUND HOUSES:

To determine the size of apparatus required for the heating of a round house, the number of stalls in the building is used as the basis for calculation. I have found from a number of tests, that each stall requires 2000 cubic feet of air per minute. This amount of air is not figured on the basis of heating the building, but it is the amount required to help thaw out the engines which come in during the winter covered with ice. Using this as a basis, I figure the size of the fan in the following manner:

Counting the number of stalls and multiplying same by 2000, I determine the amount of air required. Dividing this amount by 2400, which is the velocity of the air at the outlet, I obtain the area of the outlet. By referring to any standard catalog, I find the size of the fan required. The size of the fan determines the size of the heater, as explained before, namely, figuring the velocity of the air through the heater about 1200 feet per minute, or the free area of the heater to be 50 per cent of the total area.

The size of the ducts is either figured on velocities, or by using the equalization table.

I have found by experiments that two 15" outlets for each stall give the best results. Plate #14052 shows a design for a round house in which the main duct is placed under ground. The smaller branches from 15" up to 30" inclusive, are constructed of glazed tile. The larger tunnels are rectangular, and built

of brick or concrete.

The old practice of using galvanized iron piping overhead, has proven to be a total failure on account of the sulphur from the locomotive smoke stacks destroying the iron.

Plate #14052 is so typical in its design, that any one wishing to design a heating apparatus for a round house, can begin at the first stall and continue the piping as shown on the plate, until he reaches a point covering the number of stalls required. The last opening in the main duct will determine the size of the fan. The design shown on plate #14052 has proven so successful, that it is almost universally used by all railroads in their newly designed round houses.

DRY KILNS:

To dry any material means to remove a certain amount of moisture from that material. Hence, to design a hot blast apparatus to dry any material, the basis for calculation must be the amount of moisture to be removed from the material to be dried.

By referring to any hygrometric chart, the designer will find the amount of moisture each cubic foot of air will absorb at any temperature. Knowing the character of the material, or knowing beforehand what temperature is required to dry a certain material, the designer will immediately know the theoretical number of cubic feet of air required to remove a certain amount of moisture at that temperature. For example: To dry 1" lumber it is customary to maintain a temperature of 140 degrees in

the kiln. By referring to any chart we will find that each cubic foot of air at 140 degrees is capable of absorbing 55 grains of moisture, but tests have proven the fact that the air at 140 degrees, while it is capable of absorbing 55 grains of moisture, actually absorbs only 5 grains because only part of the air forced into the kiln becomes fully saturated, and because there is some initial moisture in the air.

Another method of calculating the air required is to provide for changing the air in the kiln once every minute. The heating coils and ducts in the kiln are readily calculated, figuring 2400 feet per minute velocity in the main duct, 1800 feet velocity through the outlets, and 1200 through the vents.

The location of the outlets and the vents is shown on plate #14053. This illustrates a so-called compartment kiln, differing from a progressive kiln in that the material is placed in the compartment and kept until dry, when the room is emptied and refilled. A progressive kiln is one in which the dry lumber is taken out at one end and the wet lumber is loaded at the coldest end.

In designing a dry kiln, the engineer must have a knowledge of how much heat the material will stand. For example: If one should attempt to dry glue at a high temperature, say 150 degrees, he would find that the glue would become case hardened, or a crust would form on the outside and the inside would remain soft and wet. Therefore, to dry glue I have learned by experience that the air must not be of a higher temperature than 75 or 80 degrees. This latter statement also applies to drying of

vegetables, apples, cereals, or any other material which is liable to be case hardened.

In drying heavy timbers. especially oak, at the first stage, or at the first twenty-four hours, the lumber is steamed so as to open up the pores, and then the temperature of the air is increased from 70 degrees up to 160 degrees, but this increase is by stages, allowing about 48 hours to each change.

AIR WASHERS.

The compulsory laws passed by several states, requiring mechanical ventilation for school houses and public buildings, and the universal adoption of the fan system for heating and ventilation has brought out another requirement, that of the purifying and washing of air for ventilating purposes.

The first attempt to prevent any dust from entering the fan was by means of cheese cloth filters. These filters, however, were only intended to cath the coarser particles of dirt contained in the air. The use of these filters, however, has been discontinued as they would clog, requiring constant attention, and reduce the free area and hence the amount of air required. To overcome this latter difficulty, a stream of water has been provided, which constantly trickles over the screens and keeps them clean. But, if the cloth is so fine that it will prevent any dust from going through, it will get stopped up by the capillary attraction of the water, and thus prevent the flow of air through it.

Plate #1 illustrates the first stage of the air washing apparatus. This apparatus consists of a large drum covered with cheese cloth. This drum revolves at a low speed, and the lower end of the drum touches the water in the tank, placed immediately underneath, and washes off whatever dirt or dust happens to come in contact with the cheese cloth. This latter apparatus has the same fault as the cheese cloth screens, and has also an additional disadvantage of clogging up and allowing entrained water to pass to the fan with the air.

The next attempt to purify and wash air is illustrated on plate #2. This apparatus is somewhat of an improvement over the first attempt, but if the coke placed between the screens is too large, then a considerable amount of dirt will pass through, and with it a certain amount of entrained water. If, however, the coke is very small, or if it is smaller than 2" in diameter, the free area through it will be very much diminished and a very large gross area of the washer will be required.

The modern air washers which are illustrated on plates 3, 4, 5, 6 and 7, consist of three parts, namely, the spray chamber, the eliminator, and the water tank. In the spray chamber is placed a number of nozzles, or spray heads, and the water is distributed over the entire area through which the air is to pass. By this means the air comes in contact with the water, and carries with it a certain amount of entrained moisture. This entrained moisture is removed from the air by the eliminator placed between the spray chamber and the inlet of the fan. This eliminator consists of a number of baffles as shown on the dif-

ferent plates, constructed in different shapes to remove the entrained water from the air.

The tank placed at the bottom, or immediately underneath the spray chamber, is so constructed, or so placed, that all the water used for washing the air, flows into this tank and from there is either wasted into the sewer, or used over and over again by means of a centrifugal pump.

There has been considerable discussion before the Engineering Societies as to which is the best method of distributing the water in the spray chamber. Some claim that a sheet of water is the proper method; some claim that a mist is the most desirable way of bringing the air and water in contact, while others claim that an immitation of nature, that is the rain effect, gives the most effective results. I have tested every air washer now in the market, and I find that a combination of a spray and a rain effect is the most efficient method of washing the air. By using a spray or sheet of water only, I find that the air traveling with a velocity of about 400 feet per minute, can at times make openings through the mist or sheet, and pass through unwashed, while under a combination of the two sprays, the air must come in contact with one or the other.

I have also found by experiments that the desirable velocity of the air through the eliminator should never be greater than 400 feet per minute. Also, that the water should be discharged through the nozzles with a pressure of not less than 20 pounds.

I have also found by actual tests that the arrangement of the baffles as shown on plates 6 & 7, namely, by placing same in a horizontal position, is giving the best results. By this latter arrangement the air is divided into horizontal strata and each stream of air, after being washed, comes through the eliminators without coming in contact with the water from other strata.

The air washers which have vertical eliminators are at a disadvantage from the fact that the upper layers of air, after being washed, will pass through to the upper part of the eliminator, but the lower layers of air will be washed in the spray chamber and then passing through the lower portion of the baffles, will come in contact with the water which has washed the upper layers of air. Thus on tests, I found that the air passing through the lower portion of the eliminator contains far more moisture than that passing through the top of the eliminator. The number of tests that I have made on air washers convinced me that the apparatus is efficient for washing, and no more. This is to contradict statements made by some manufacturers that they are not only washing the air, but are cooling it. This latter fact I have discussed in a paper before the American Society of Heating and Ventilating Engineers, and have proven that the cost of cooling air is so great that it is almost a commercial impossibility..

I have also proven that air washing adds humidity to the air in proportion to the temperature of the air and water.

In the winter time if an air washer is used with a heating apparatus, it is possible to maintain a constant humidity in the building by increasing or decreasing the temperature of the air before it reaches the spray chamber. But, if an air washer is used in summer, it is almost impossible to reduce the humidity of the air unless artificial means are used, or unless refrigeration is used to condense that humidity. These latter results I found on tests I have made with the temperature of 80 degrees outside and the relative humidity of 85 per cent. Air at 80 degrees coming in contact with water at 75 or 80, will absorb moisture almost to the point of total saturation, and in order to remove that humidity refrigeration is necessary.

TABLE #1.

Basement.

No. of Room	Dimen. of Room	Cont. of Room	No. of Occ.	Use of Room	Time of Chge.	Air Sup-ply	Size Heat Flue	Size Vent Flue	Size Heat Reg.	Size of Duct
1	25x30x12	9000		Toil.	10	900	16x16	16x16	18x24	8x18
2	30x80x15	36000		Gym.	12	3000	36x20	36x20	24x30	26x18
3	25x30x12	9000		Dom.Sc.	9	1000	16x16	16x16	18x24	9x18
4	25x30x12	9000		Lab.	9	1000	16x16	16x16	18x24	9x18
5	54x30x12	19440		Lab.	9	2200	32x16	32x16	24x36	20x18
6	25x30x12	9000		Lunch	10	900	16x16	16x16	18x24	8x18

First Floor.

No. of Room	Dimen. of Room	Cont. of Room	No. of Occ.	Use of Room	Time of Chge.	Air Sup-ply	Size Heat Flue	Size Vent Flue	Size Heat Reg.	Size of Duct
101	26x30x13		50	Class		1500	16x22	16x22	24x30	13x18
102	48x30x13		90	Class		7 2800	16x22 16x22	16x22 16x22	24x36	24x18 24x18
103	26x30x13		50	Class		1500	16x22	16x22	24x30	13x18
104	26x30x13		50	Class		1500	16x22	16x22	24x30	13x18
105	26x30x13		50	Class		1500	16x22	16x22	24x30	13x18
106	26x30x13		50	Class		1500	16x22	16x22	24x30	13x18
107	26x30x13		50	Class		1500	16x22	16x22	24x30	13x18
108	26x30x13		50	Class		1500	16x22	16x22	24x30	13x18
109	21x110x13	30030		Cor.	15	2000			24x48	18x18

TABLE #1. Continued.

Second Floor.

No. of Room	Dimen. of Room	Cont. of Room	No. of Occ.	Use of Room	Time of Chge.	Air Sup-ply	Size Heat Flue	Size Vent Flue	Size Heat Reg.	Size of Duct
201	20x30x13		50	Class		1500	16x20	16x20	24x30	13x18
202	25x21x13		35	Class		1000	16x14	16x14	18x24	9x18
203	26x30x13		50	Class		1500	16x20	16x20	24x30	13x18
204	34x30x13		65	Class		2000	20x20	20x20	24x36	18x18
205	20x30x13	10140		Sess.	10	1000	14x16		18x24	9x18
206	52x106x13	71656		Sess.	10	7000	72x20		24x36 24x36 24x36	60x18

Totals.

Basement	9000
First Floor	15300
Second Floor	14000

38300 total air supply, or 40000 cubic feet being the nearest standard.

4 - 9-3/4 housing fan at 1/2 oz. pressure.

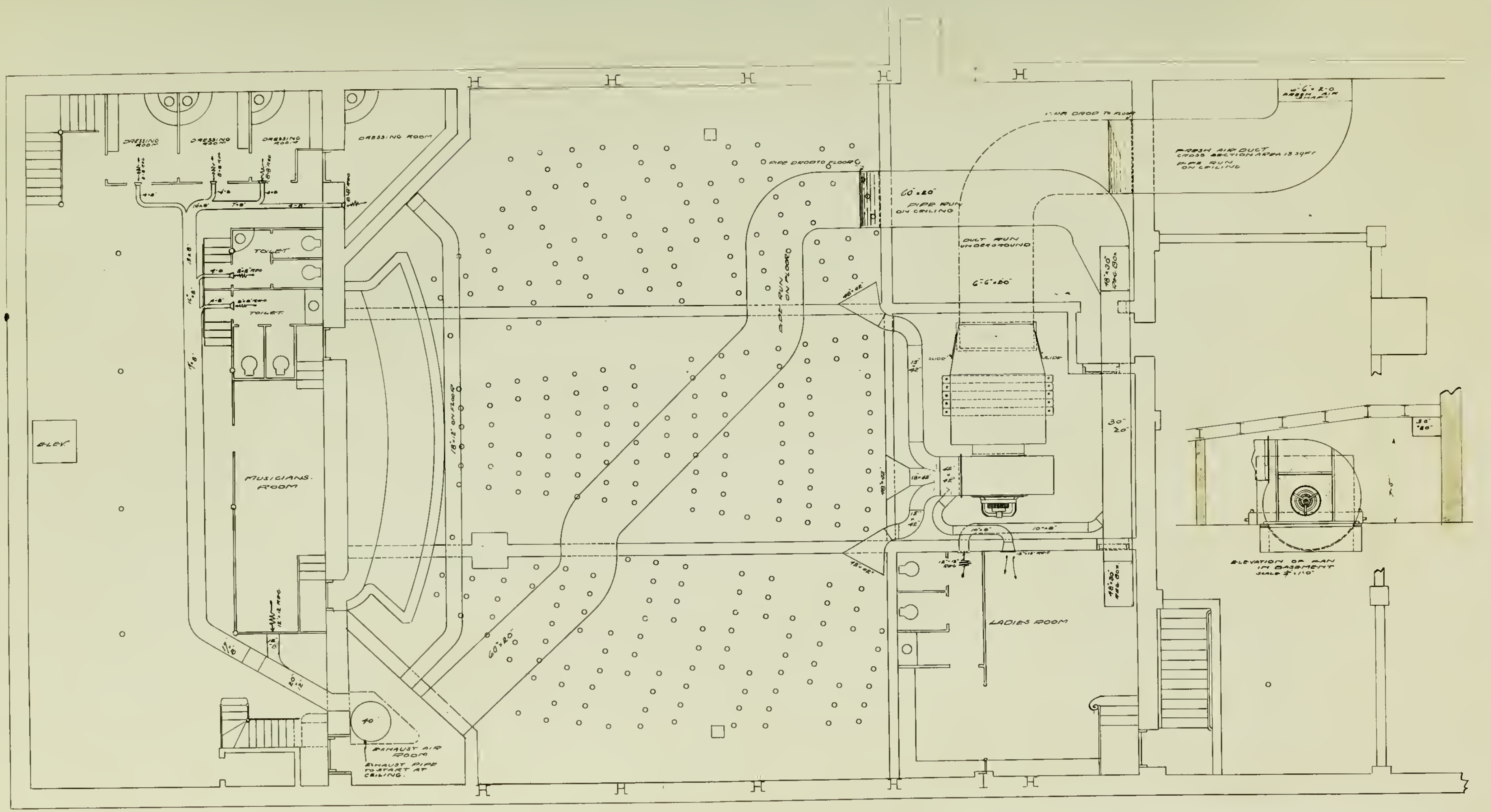
Heater double group 6 X 7 - 14 rows deep.

Temp. Coils " " " " " 8 " "

TABLE #2.

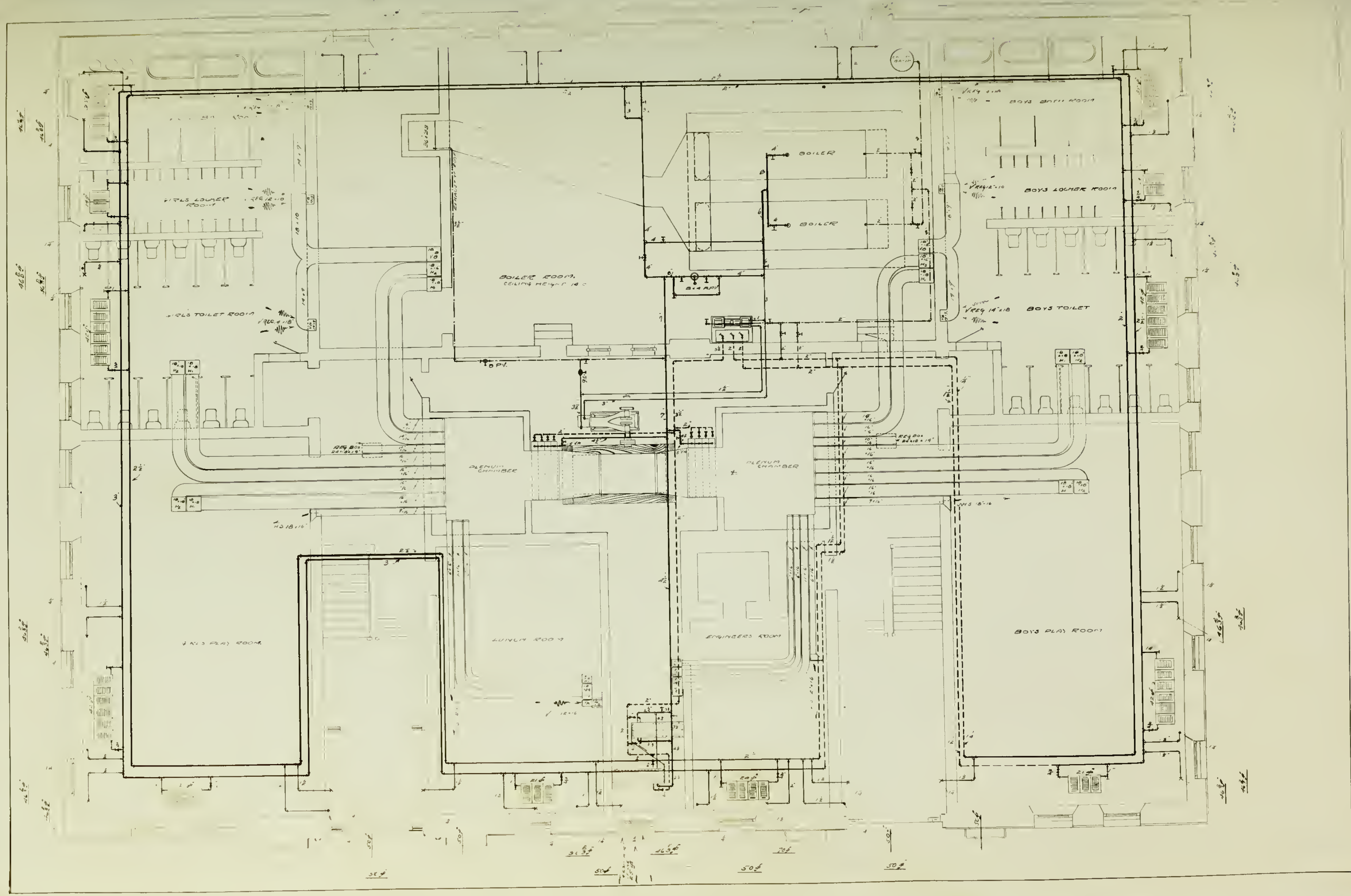
No. of Room	Dimen. of Room	Cont. of Room	No. of Occ.	Use of Room	Time of Chge.	Air Supply	Size Heat Flue	Size Vent Flue	Size Heat Reg.	Size of Duct
201	23x29x12	8004	41	Grade	P	1300	268	18x16	20x24	12x18
202	25x29x12	8868	50	Grade	P	1500	309	20x16	24x30	13x18
203	25x35x12	10500	60	Grade	P	1800	371	24x16	24x36	14x18
204	19x19x8$\frac{1}{2}$	6678		Office	8	800	165	16x10	18x24	11x12
205	30$\frac{1}{2}$x21x12	7686	41	Lab.	P	1300	268	18x16	20x24	12x18
206	14x25x12	4200		Lib.	8	500	103	8x16	12x18	8x10
207	39$\frac{1}{2}$x31x13	15925	80	High R.	P	2500	515	32x16	24x36	23x18
208	51$\frac{1}{2}$x17x12	3168	20	Rec.R.	P	600	123	8x16	10x18	8x12
209	17x18x12	3672	20	Rec.R.	P	600	123	10x13	12x18	8x12
101	23x29x12	8004	41	Grade	P	1300	268	15x16	20x24	12x18
102	25$\frac{1}{2}$X29x12	8868	50	Grade	P	1500	309	20x16	20x36	13x18
103	25x35x12	10500	60	Grade	P	1800	371	24x16	24x36	14x18
104	12x19x8$\frac{1}{2}$	1938		Teach.	10	200	41	8x8	8x10	4x8
105	25x35x12	10500	60	Grade	P	1800	371	24x16	24x36	14x18
106	25x29x12	8700	50	Grade	P	1500	309	20x16	24x30	13x18
107	23x29x12	8004	41	Grade	P	1300	268	18x16	20x24	12x18
1	22x23x9	6534		Dom.Sc.	10	700	144	9x16	12x18	10x12
2	24x32x9	6912		Manual Trng.	10	700	144	9x16	12x18	10x12
3	12x33x9	3564		Boys' Toilet	10		82	8x12	12x18	
4	22x19x9	3762		Girls' Toilet	10		82	8x12	12x18	

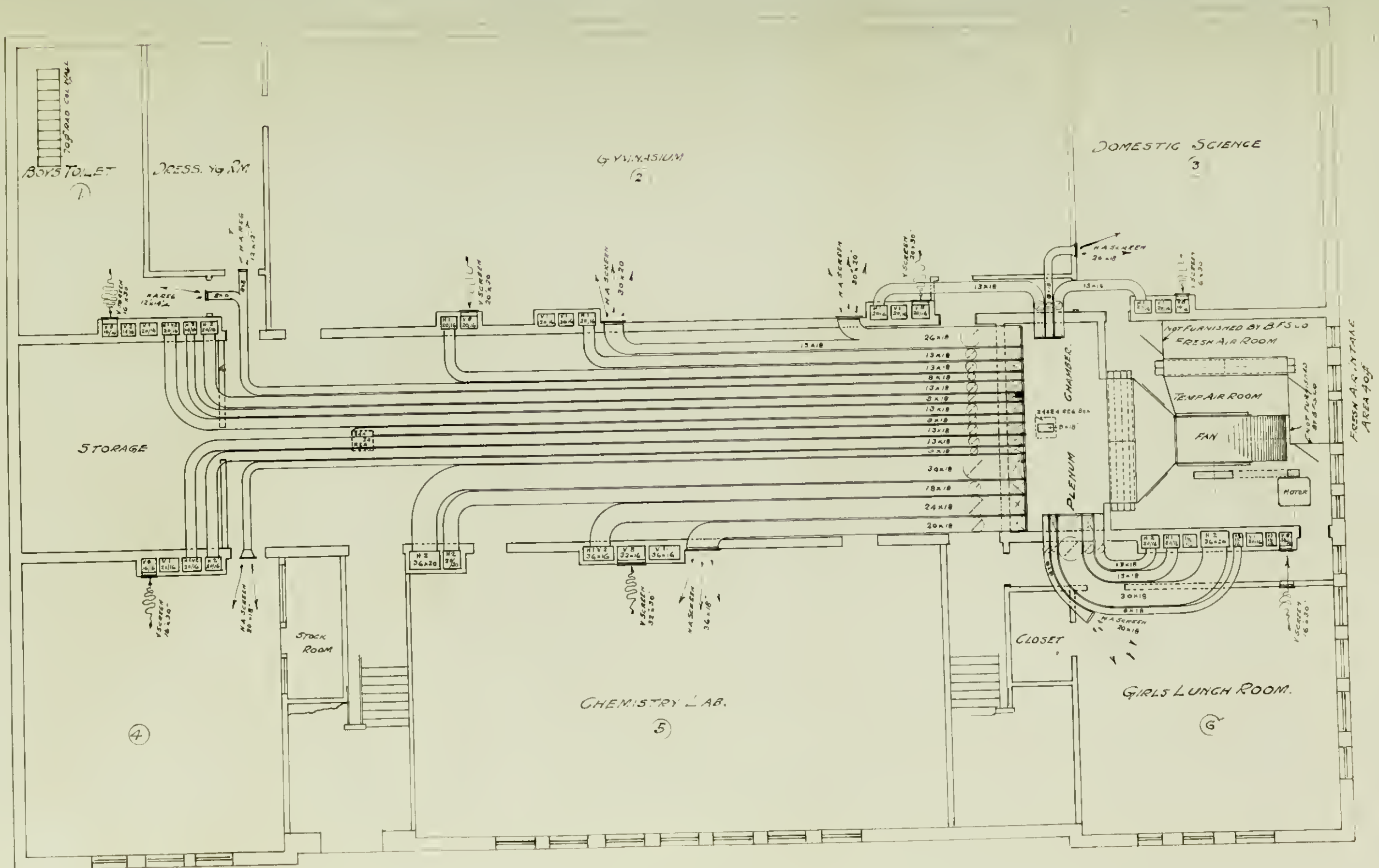
1-6' fan at 1/2 oz. pressure.



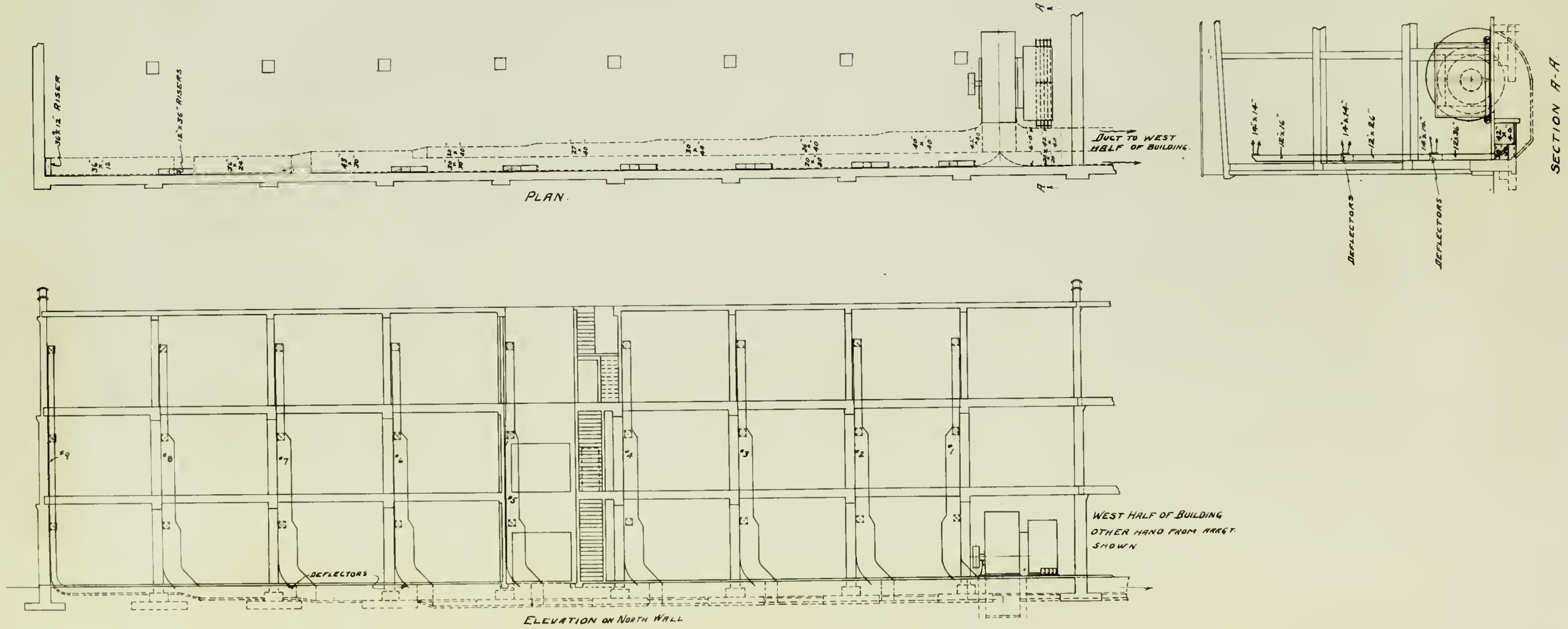
BASEMENT PLAN

14044


BOYS BATH ROOM
BOYS LOCKER ROOM
BOYS TOILET
BOYS PLAY ROOM
BOILER
BOILER
BOILER ROOM
CEILING HEIGHT 14'0"
PLENUM CHAMBER
PLENUM CHAMBER
ENGINEERS ROOM
LUNCH ROOM
GIRLS LOCKER ROOM
GIRLS TOILET ROOM
GIRLS PLAY ROOM
14045

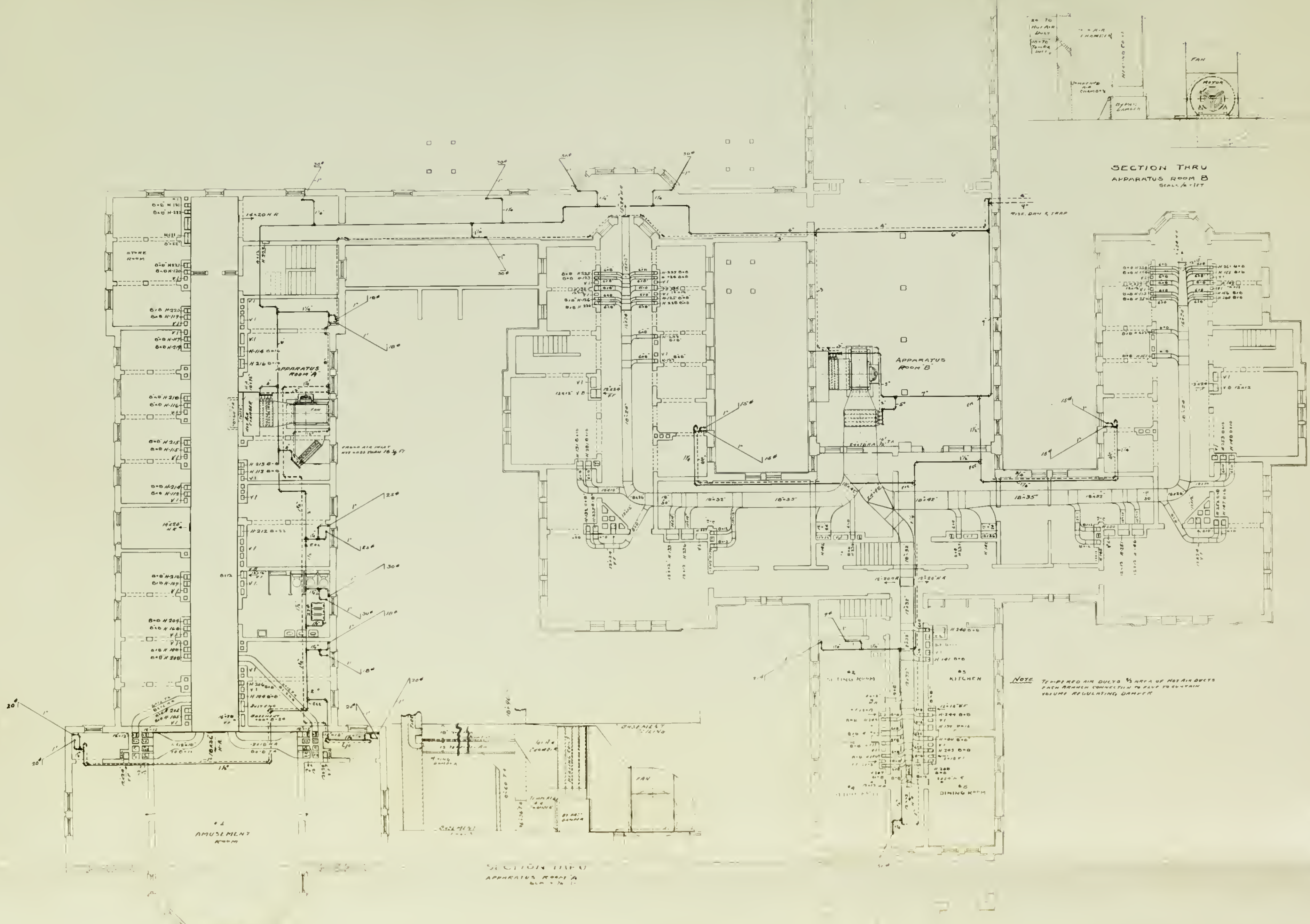


Basement Plan



36"x12" RISER
12"x36" RISERS
DUCT TO WEST HALF OF BUILDING
PLAN
SECTION A-A
DEFLECTORS
DEFLECTORS
WEST HALF OF BUILDING OTHER HAND FROM ARRGT. SHOWN
DEFLECTORS
ELEVATION ON NORTH WALL

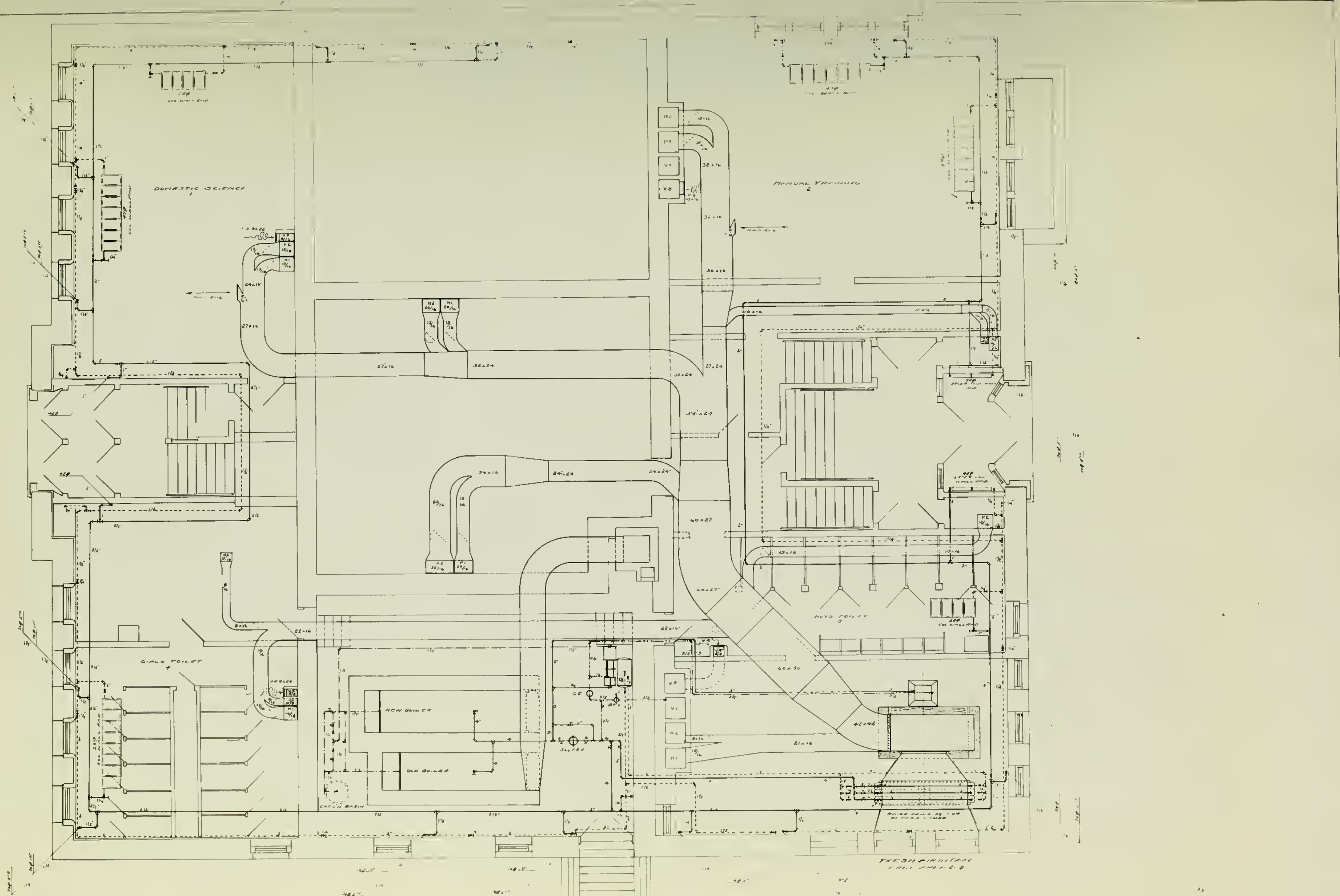
14047



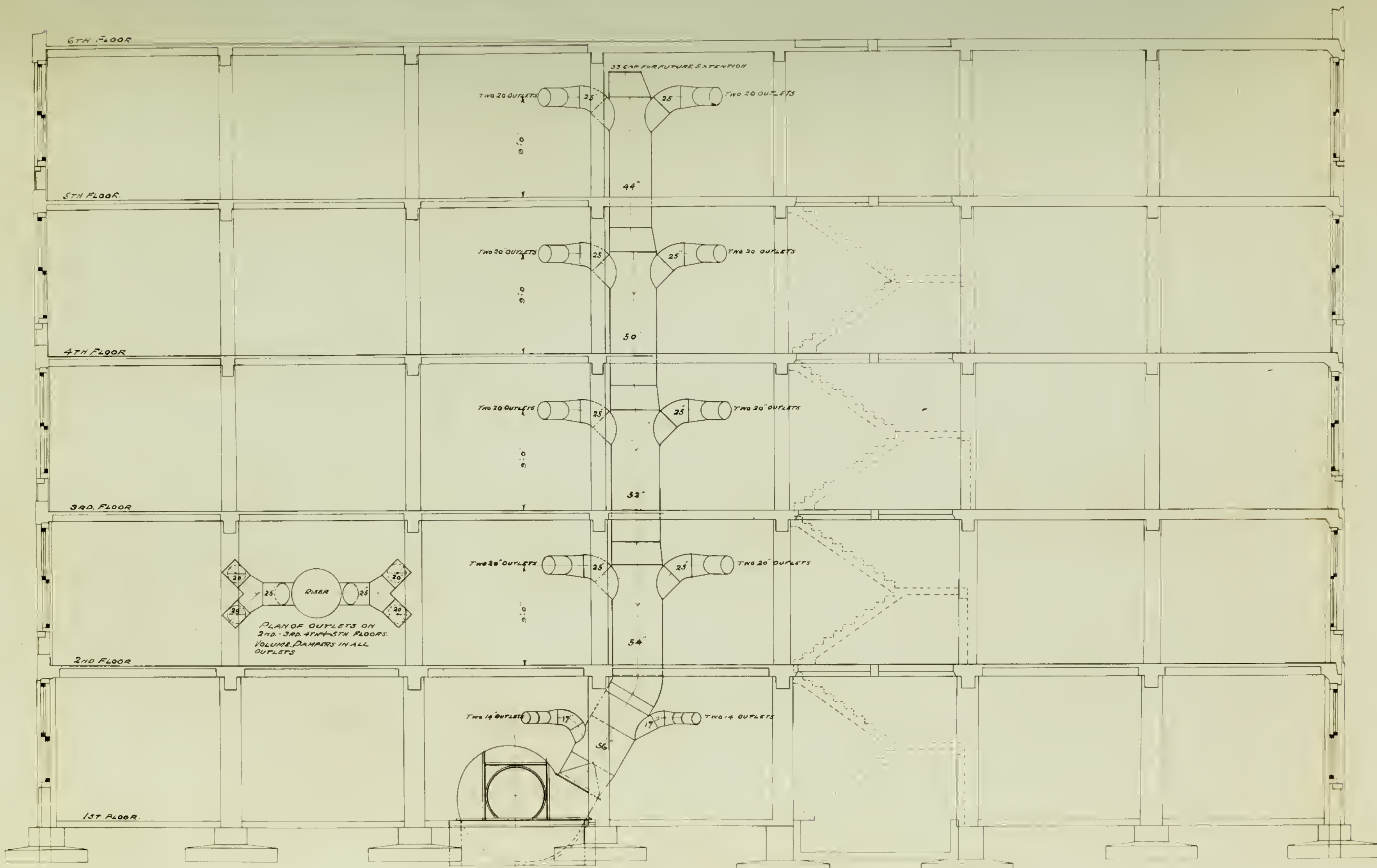
BASEMENT PLAN

14048

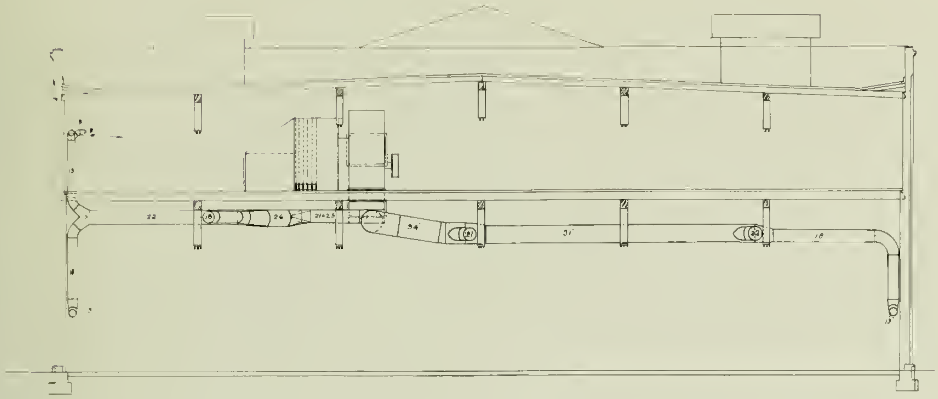
4048



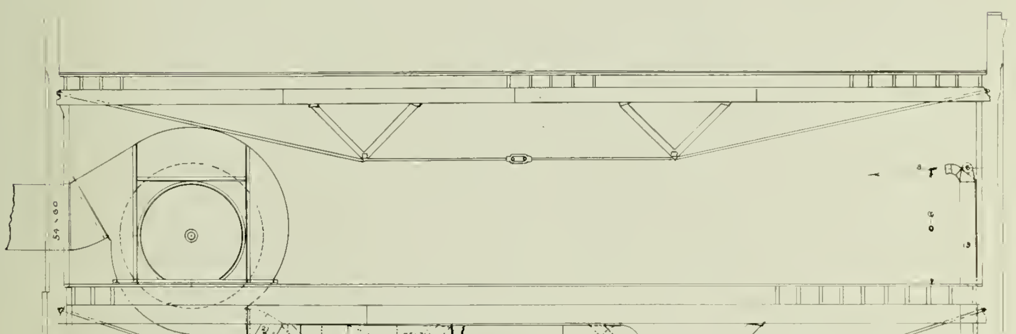
BASEMENT PLAN



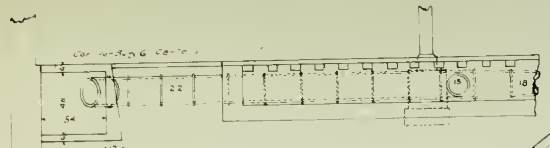
SECTION ON LINE A-A



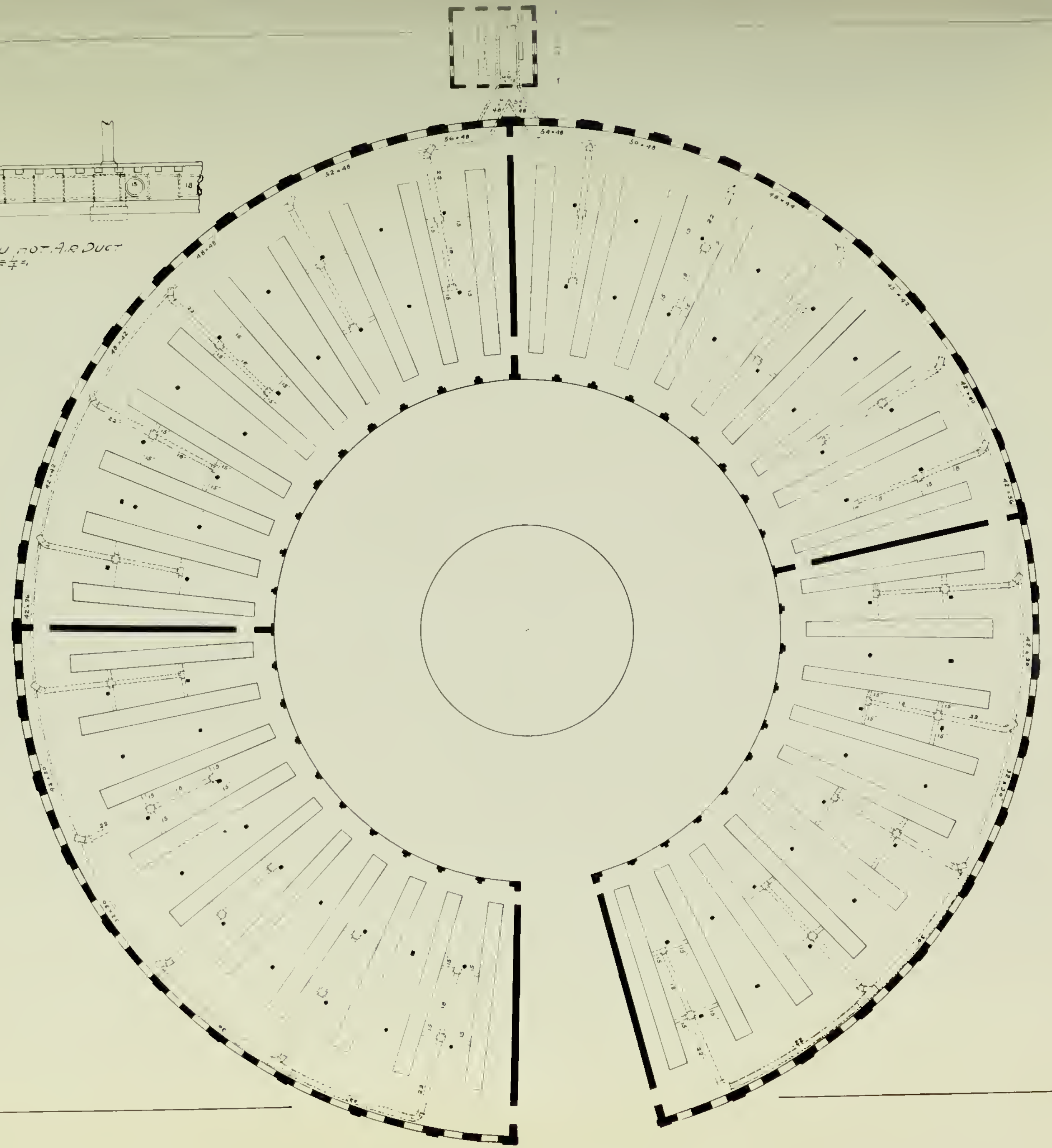
SECTION ON LINE D-D
SCALE 1/8" = 1'



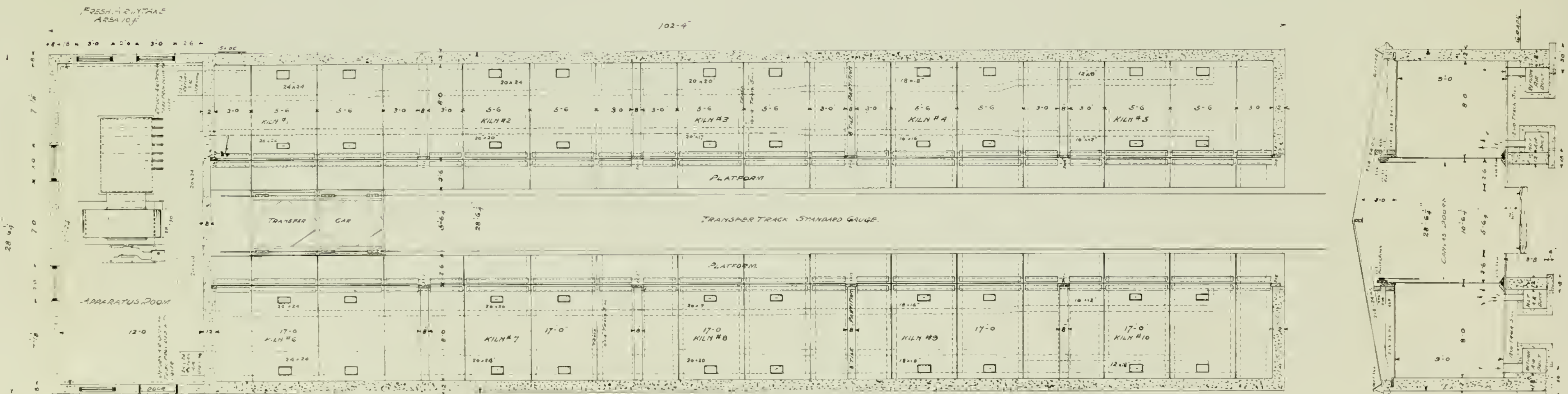
SECTION ON LINE C-C.
SCALE 1/4" = 1'



SECTION THRU HOT AIR DUCT
SCALE $\frac{1}{4}$ = 1



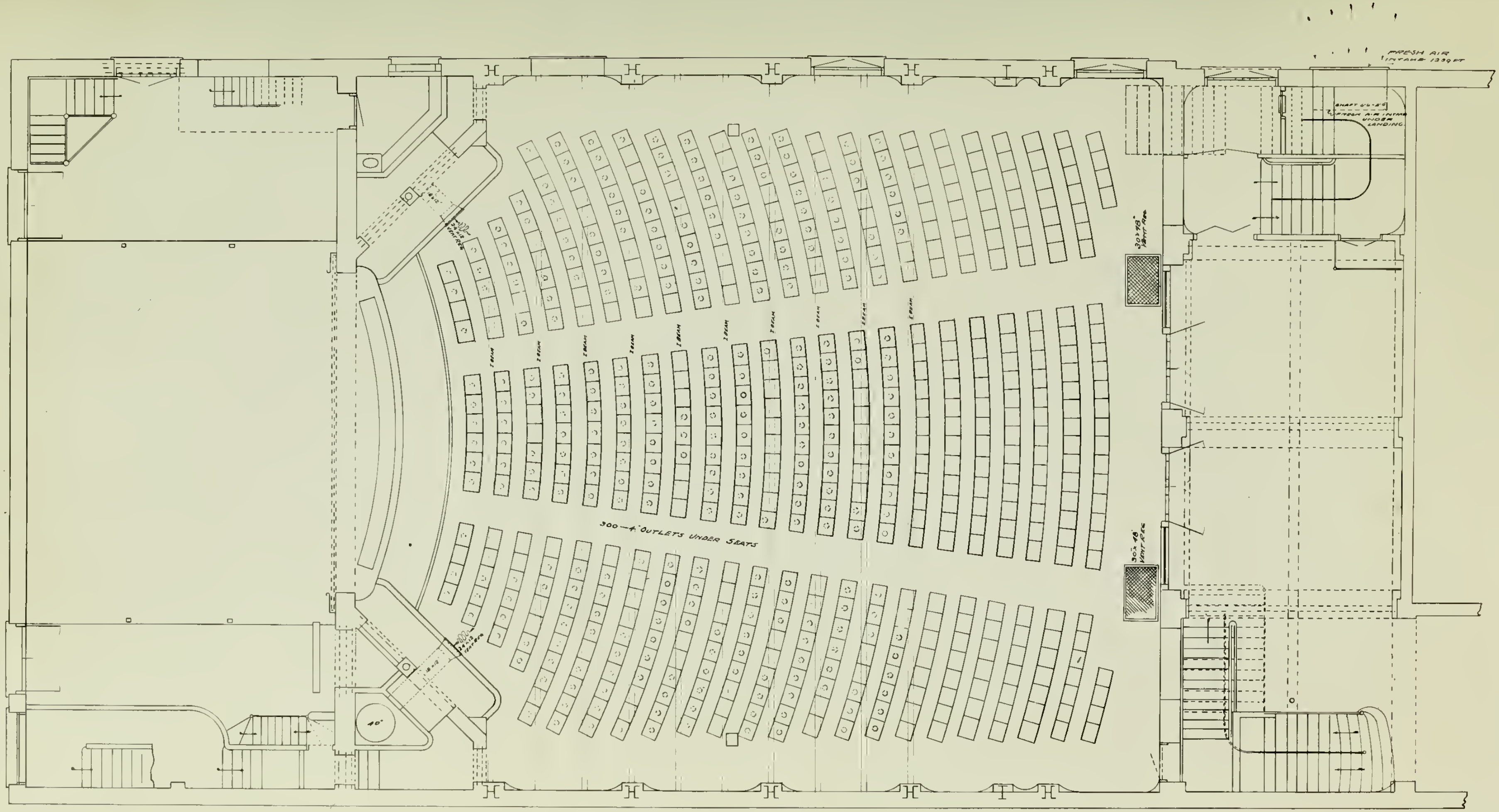
14052



FLOOR & FOUNDATION PLAN.

89'-8"

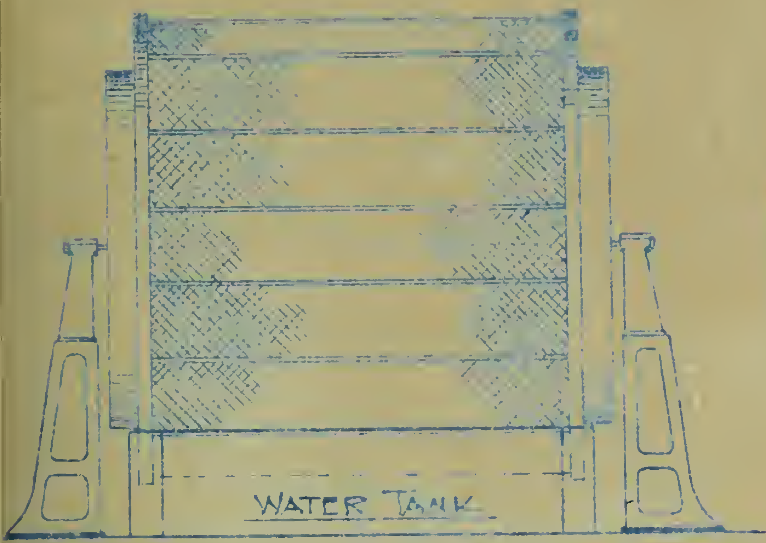
NOTE
ALL HOT AIR OPENINGS IN KILNS 6×12 WITH SLIDE DAMPERS
RETURN " " " 8×12 " "



AUDITORIUM FLOOR.
SCALE ⅛" = 1'-0"

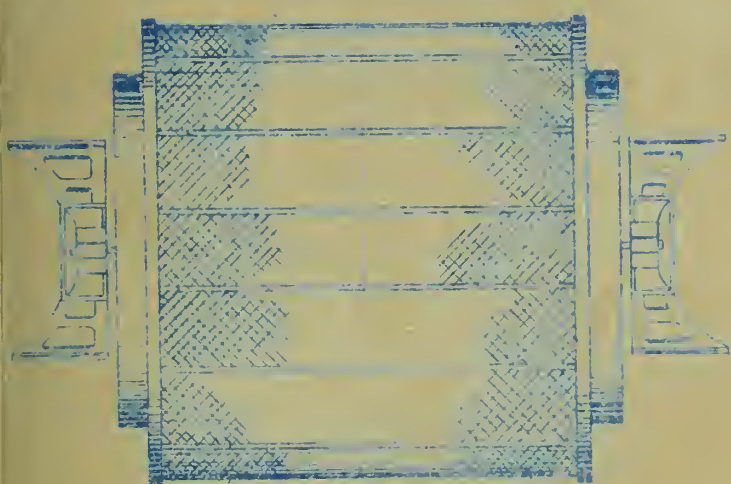
Average Results
of
Tests of Condensation of Steam in Blower System of Heating.

	One Section Heating Surface 180.85 Sq. Ft.			Two Sections Heating Surface 361.7 Sq. Ft.			Three Sections Heating Surface 542.6 Sq. Ft.			Four Sections Heating Surface 723.4 Sq. Ft.			Five Sections. Heating Surface 904.4 Sq. Ft.			Seven Sections Heating Surface 1266. Sq. Ft.		
Number of Run	1	2	3	4	5	6	7	8	9	16	17	18	10	11	12	13	14	15
1 Mean Pressure in Coils Lbs.	12.62	35.5	54.0	13.1	35.5	57.0	14	34.5	56.5	13.0	12.5	12.7	13.0	34.0	53.2	13.2	58.3	53.6
2 Temperature of Steam °F	244.1	280.5	302.0	246.3	281.0	302.7	245.0	280.0	303.7	245.0	244.0	246.5	245.0	279.0	300.7	246.3	291.0	310.0
3 Total Steam Condensed Per Hour.	263.	294.	320.	458.	465.	511.	575.	591.0	647.	769.	518.	705.	764.	937.	1014	970.0	1088.	1231.
4 Steam Condensed Per Hour Lbs Per Sq. Ft.	1.4	1.64	1.7	1.27	1.28	1.42	1.05	1.09	1.19	1.06	0.72	.56	0.84	1.04	1.12	0.76	0.865	0.97
5 B.T.U. Per Hour Lbs Per Sq. Ft.	1340.	1413.	1582.	1108.5	1167.	1267.	986.	993.	1053.	1003.6	673.3	529.8	800.6	931.8	991.0	703.3	759.0	852.0
6 Temperature of Air Received °F	65.	65.0	65.9	71.17	72.7	73.8	74.0	73.0	70.2	73.2	73.33	73.5	66.25	70.6	74.9	77.0	78.0	75.7
7 " " " " Delivered °F	112.0	112.0	114.2	130.0	114.7	147.0	145.0	153.0	166.2	150.3	152.3	167.75	169.75	191.5	203.7	182.5	215.0	226.5
8 " " " " Mean °F	88.5	88.5	90.05	100.6	108.7	110.4	110.0	113.0	118.3	111.7	112.8	118.12	118.0	131.0	139.3	129.5	146.5	151.1
9 " " " " Increased °F	47.0	47.0	48.3	58.8	72.0	73.1	71.5	80.0	96.0	77.0	79.0	89.3	103.5	121.0	128.8	105.5	137.0	150.9
10 Expansion of Air by Heating.	1.08	1.09	1.085	1.115	1.135	1.138	1.13	1.15	1.18	1.14	1.15	1.16	1.19	1.23	1.24	1.18	1.25	1.28
11 Velocity of Air Entering Coils Ft. Per Min.	511.	485.	507.	517.	480.	494.	506.	452.	488.	664.	482.	246.	456.	446.	430.	486.	452.	499.
12 Revolutions of Fan Wheel Per Minute	400.	400.	404.	400.	400.	404.	400.	404.	400.	552.	404.	204.	400.	404.	402	400.	402.	403.
13 Peripheral Speed of Fan Feet Per Min.	5026.	5026.	5070.	5026.	5026.	5070.	5026.	5040.	5040.	6440.	5070.	2568.	5026	5050.	5050	5026	5040.	5065.
14 Difference Temp Bet. Steam and Entering Air.	179.1	215.5	236.1	175.1	218.3	248.9	171.	207.	233.5	172.8	140.7	143.0	179.	208.4	225.8	149.3	213.0	234.3
15 " " " " Mean Air	155.6	192.0	212.0	146.2	172.3	192.3	135.	167.	185.5	133.3	131.2	128.3	127.	148.	161.4	116.5	144.5	159.6
16 B.T.U. Per Sq. Ft. Per Hr. for Diff. Temp. (14) Per Deg.	7.5	6.6	6.8	6.34	5.34	5.07	5.78	4.8	4.48	5.83	4.82	3.71	4.5	4.5	4.42	4.7	3.65	3.65
17 " " " " " " " (15) " "	8.63	7.4	7.49	7.56	6.73	6.59	7.31	5.95	5.7	7.53	5.16	4.13	6.32	6.3	6.15	6.05	5.36	5.35
18 Probable B.T.U. Per Hr. Ent. Air Zero, Per Sq. Ft. H.S.	1615.	1655.	1835.	1308.	1400.	1510.	1258.	1475.	1608.	1275.	815.	683.	1007.	1140.	1220.	973.	987.	1055.
19 Probable Steam Cond. Ent. Air Zero, Per Sq. Ft. Lbs.	1.67	1.72	1.90	1.43	1.46	1.56	1.35	1.53	1.67	1.33	.845	.705	1.05	1.19	1.27	.965	1.02	1.09
20 Volume of Air Received Cu. Ft. Per Hour.	882000.	829000.	867000.	884000.	835000.	845000.	865000.	782000.	834000.	18950.	13750.	7066.	781000.	762000.	736000.	800031.	772500.	767000.
21 Velocity in Discharge Duct Ft. Per Min.	2860.	3090.	3140.	3270.	3140.	3460.	3460.	3080.	3110.	4210.	2980.	1505.	3150.	3115.	3140.	3150.	3140.	3160.
22 Ratio of Velocity of Air to Peripheral Vel. of Fan.	0.565	0.611	0.622	0.645	0.625	0.682	0.68	0.61	0.618	0.65	.59	.59	.62	.615	0.62	0.625	0.622	0.625



FRONT ELEVATION

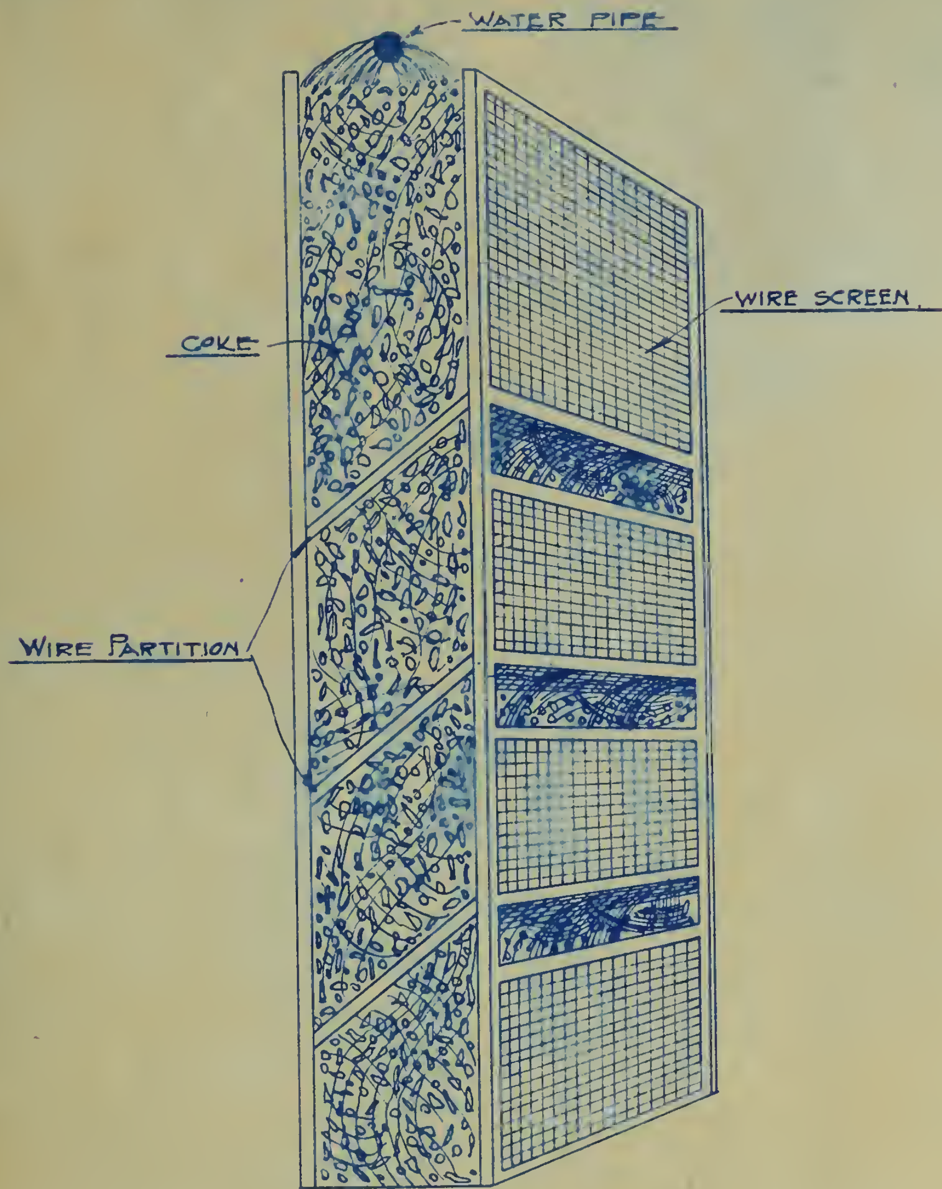
SIDE ELEVATION



PLAN

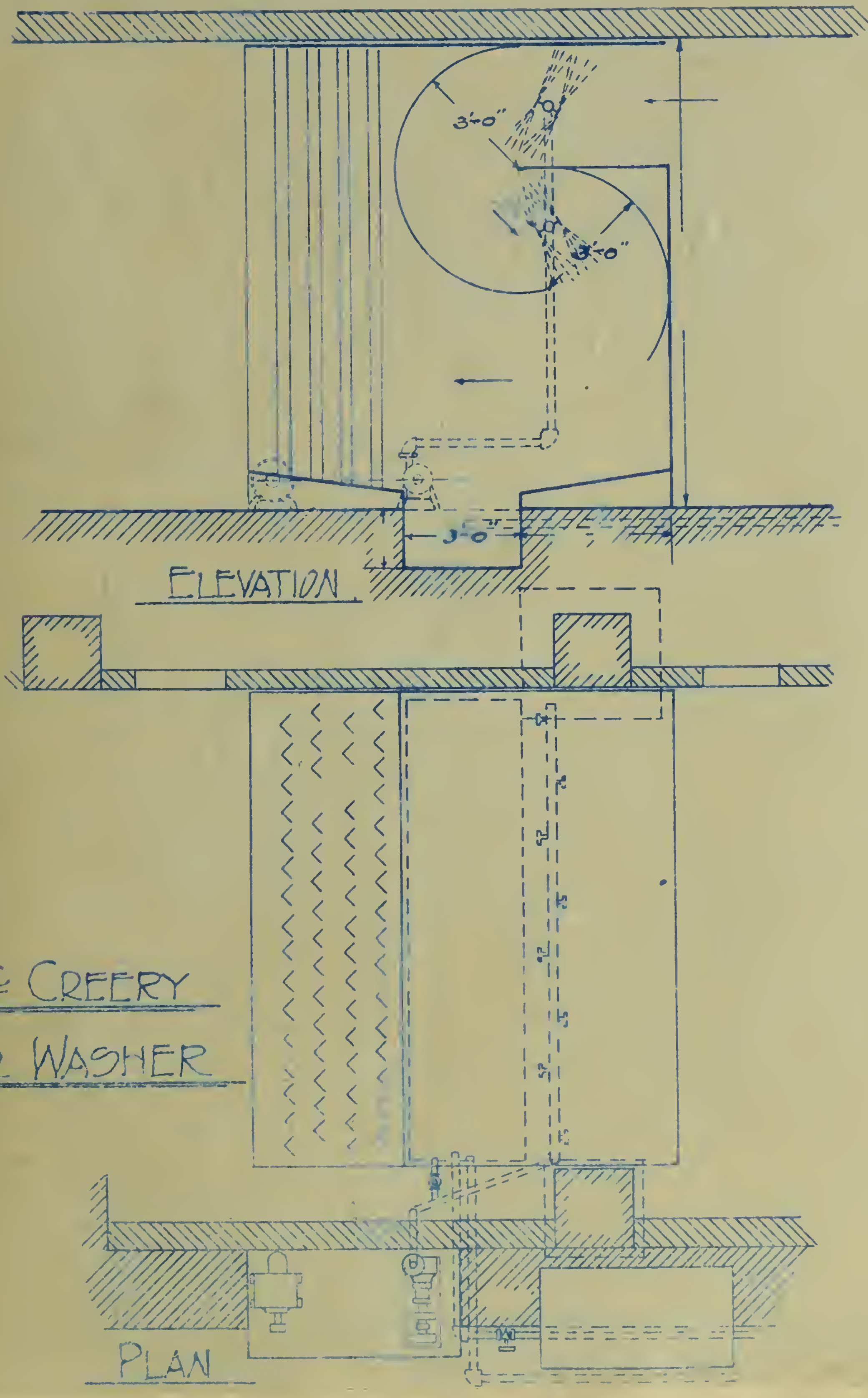
"SIROCCO"
AIR FILTER

Nº 2.

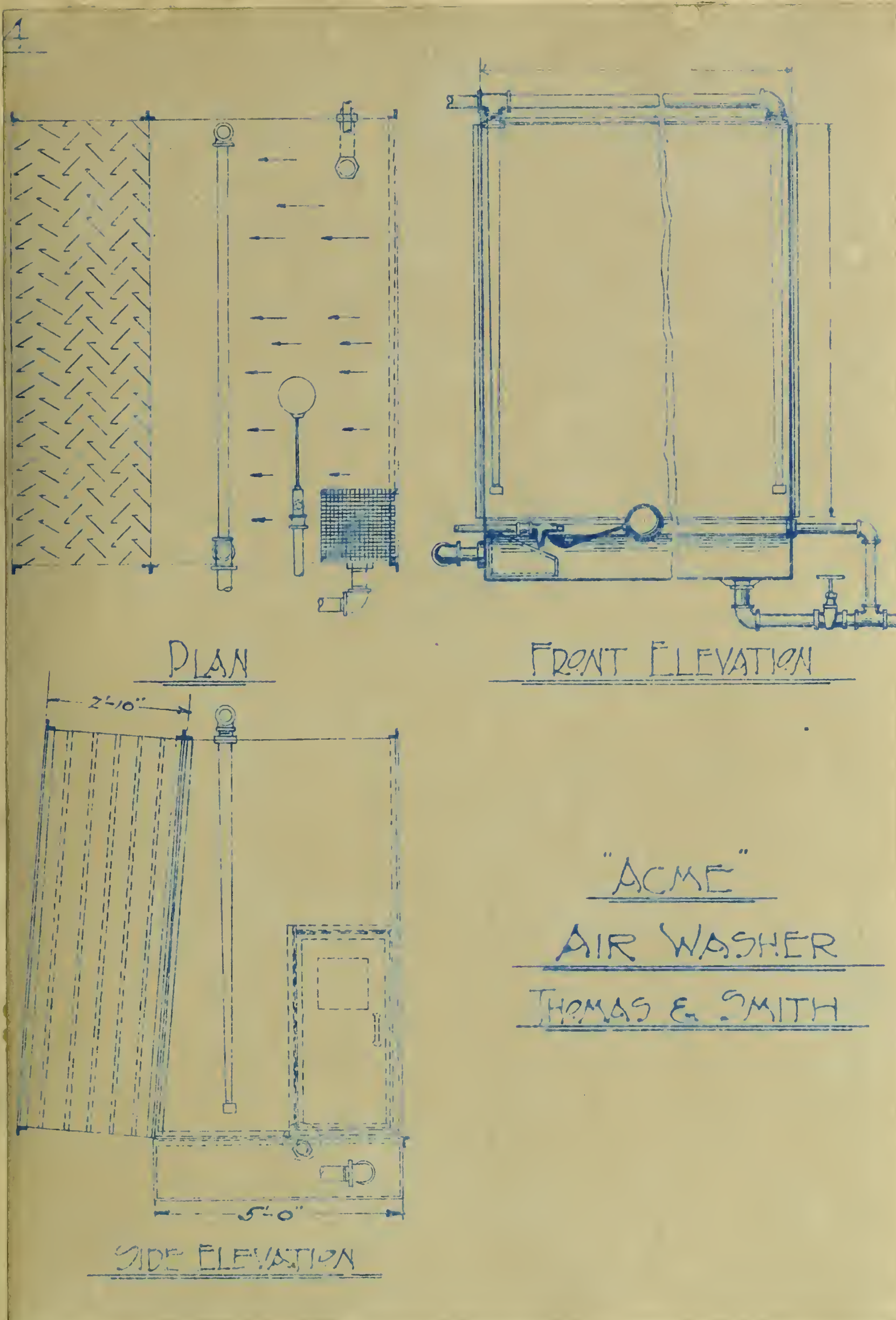


COKE SCREEN

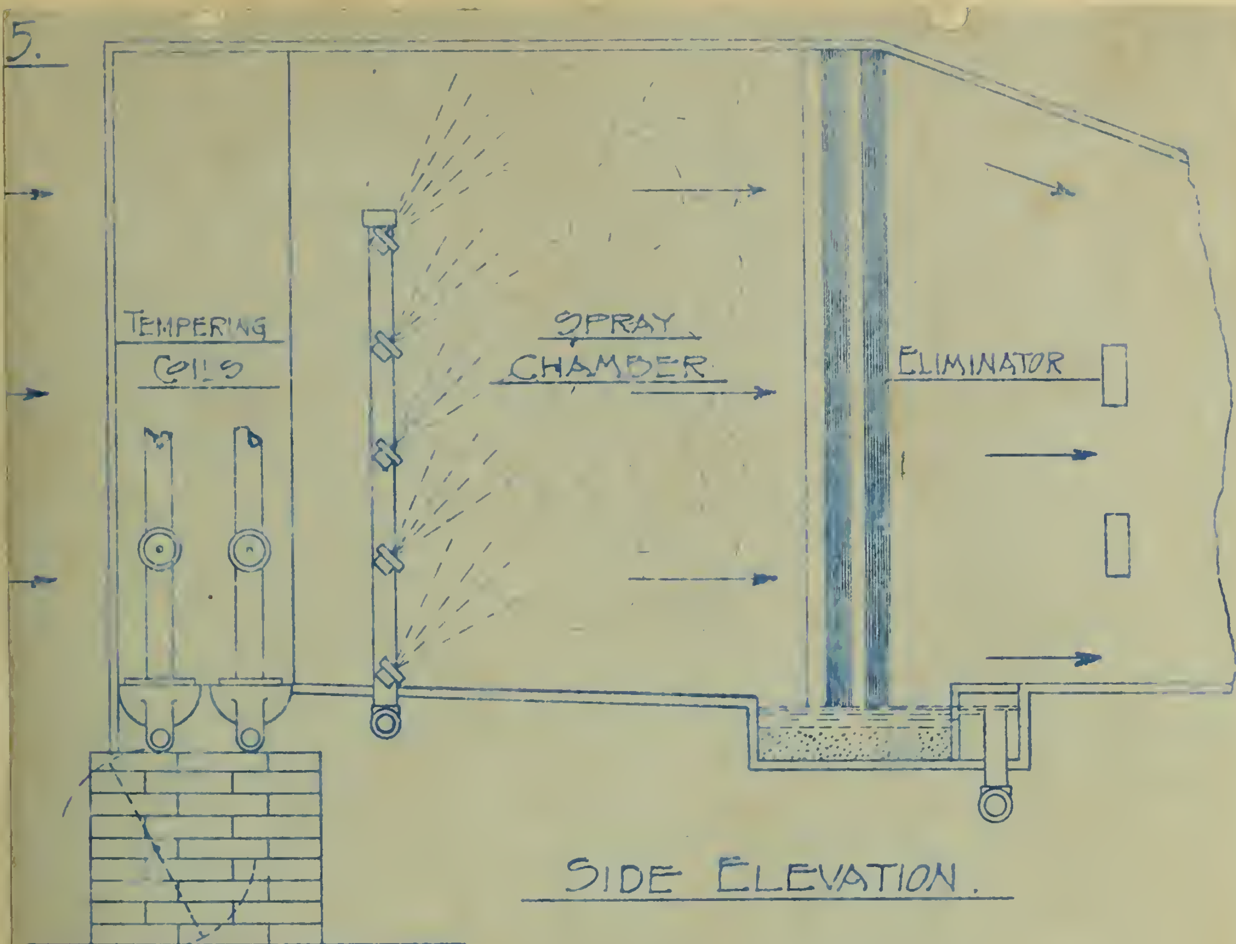
3



McCREERY
AIR WASHER


A
2
PLAN
FRONT ELEVATION
2'-10"
5'-0"
SIDE ELEVATION
"ACME"
AIR WASHER
THOMAS & SMITH

5.



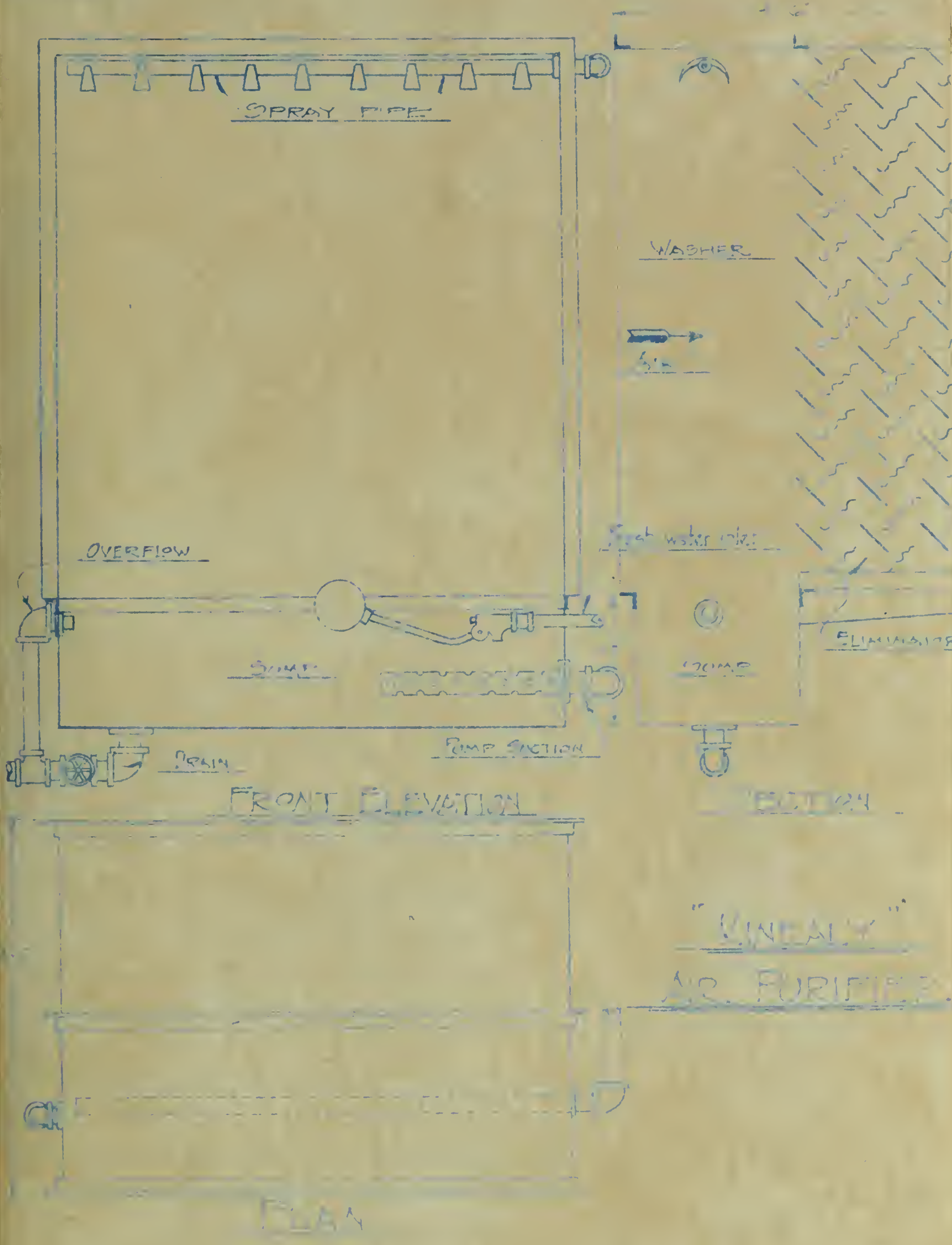
SIDE ELEVATION.

DETAILS OF ELIMINATOR.

"BUFFALO"
AIR WASHER

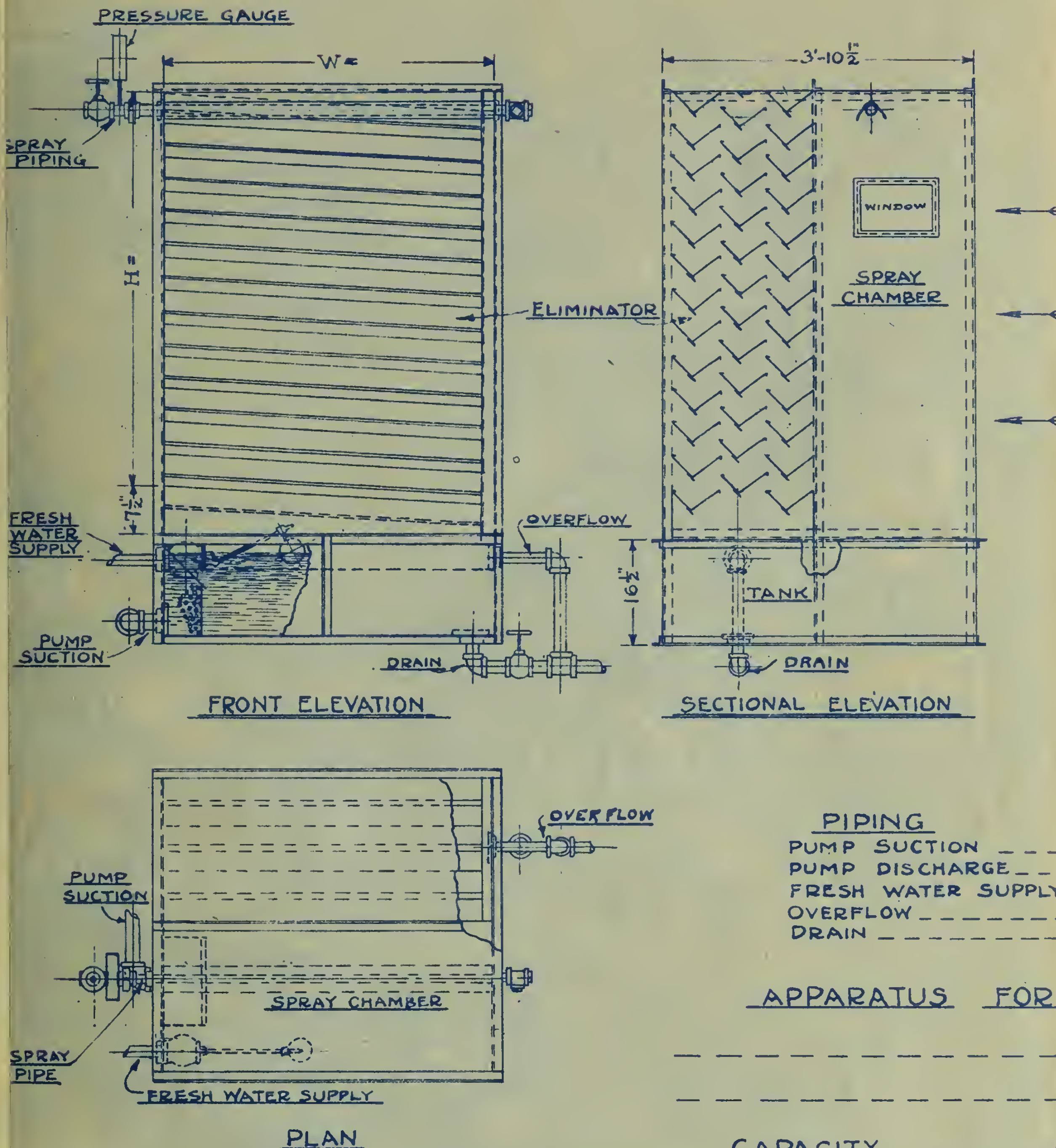
DETAILS OF SPRAY NOZZL

No 6



"KINEALY"

AIR PURIFIER



PIPING

PUMP SUCTION _ _ _
PUMP DISCHARGE _ _
FRESH WATER SUPPLY
OVERFLOW _ _ _ _ _ _
DRAIN _ _ _ _ _ _ _ _

APPARATUS FOR

_ _ _ _ _ _ _ _ _ _ _ _ _ _

_ _ _ _ _ _ _ _ _ _ _ _ _ _

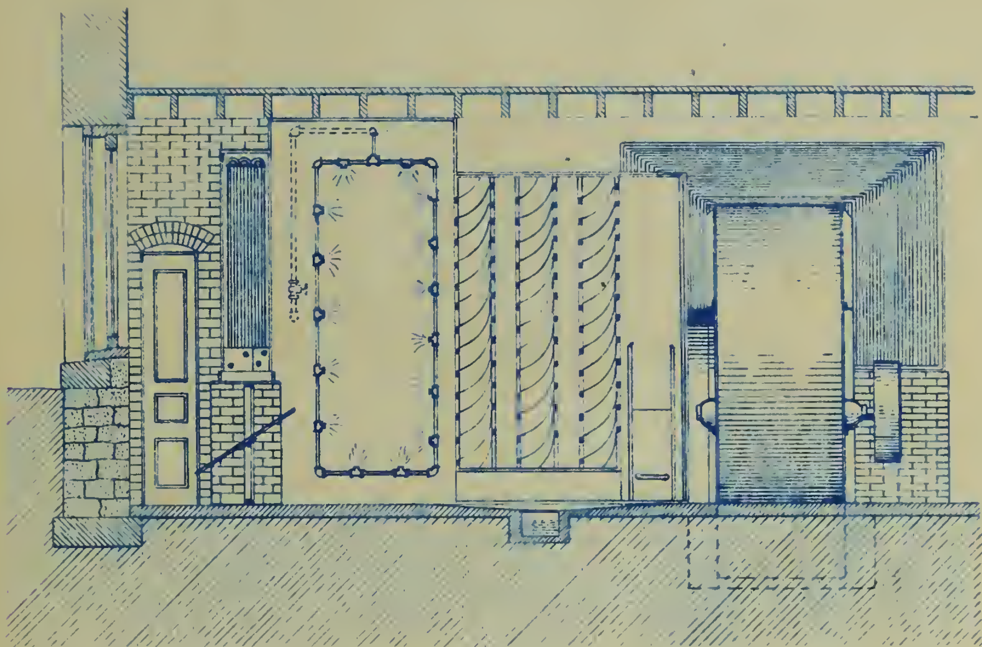
CAPACITY _ _ _ _ _ _ C

THE WEBSTER AIR WASHER AND HUMIDIFIER

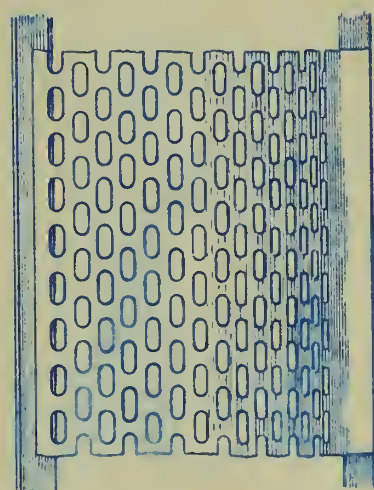
PATENT APPLIED FOR.

AIR CLEANSING = AIR COOLING = HUMIDITY CONTROL

WARREN WEBSTER & CO. CAMDEN N. J.



SIDE ELEVATION



DETAILS

NEW YORK BLOWER Co'S AIR WASHER